IDA

INSTITUTE FOR DEFENSE ANALYSES

Performance in December 1996 Hand-Held Landmine Detection Tests at APG, Coleman Research Corp. (CRC), GDE Systems, Inc. (GDE), and AN/PSS-12

Anne M. Andrews
Thomas W. Altshuler
Erik M. Rosen
Lisa J. Porter

March 1998

Approved for public release; distribution unlimited.

IDA Document D-2126

Log: H 98-000073

This work was conducted under contract DASW01 94 C 0054, Task T-AI2-1473, for DDR&E, OUSD(A&T), Mine Countermine Division. The publication of this IDA document does not imply Department of Defense endorsement of factual accuracy or opinion, nor should the contents be construed as reflecting the official position of that Agency.

INSTITUTE FOR DEFENSE ANALYSES

IDA Document D-2126

Performance in December 1996 Hand-Held Landmine Detection Tests at APG, Coleman Research Corp. (CRC), GDE Systems, Inc. (GDE), and AN/PSS-12

Anne M. Andrews
Thomas W. Altshuler
Erik M. Rosen
Lisa J. Porter

PREFACE

This document was prepared for the Director of Defense Research and Engineering, Office of the Under Secretary of Defense (Acquisition and Technology) under a task entitled "Technical Support to Communication and Electronics Command (CECOM) Night Vision Electronic Sensor Directorate (NVESD) Mine Detection Program."

We greatly appreciate the comments of Mr. Richard Weaver of the Night Vision Electronic Sensor Directorate and Dr. David Sparrow of the Institute for Defense Analyses. Their criticisms greatly improved the quality of this document.

CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

A. TEST OBJECTIVE

In December 1996, a test of three mine detection systems was held at Aberdeen Proving Ground (APG), MD. This test compared prototype landmine detection systems manufactured by two contractors, Coleman Research Corporation (CRC) and GDE Systems, Inc. (GDE), with the AN/PSS-12, the Army's currently fielded electromagnetic induction mine detector. This test was a follow-on to the U.S. Army Bosnia Countermine Task Force sponsored demonstration of landmine detection systems at Fort A.P. Hill, Virginia, held in March 1996. The two prototype systems under consideration integrate a ground-penetrating radar (GPR) with an electromagnetic induction metal detector. In the CRC system, called the Drop In GPR Sensor (DIGS), a 1–3 GHz radar is added to the AN/PSS-12. The GDE system consists of a GPR in the 0.5 to 3.0 GHz band coupled to a metal detector. The metal detector system consists of the AN/PSS-12 control and sense electronics combined with a transmit/receive coil designed by GDE.

B. TEST DESCRIPTION

The three mine detection systems were tested on eighteen 1.5 m by 50 m lanes. The total number of landmines emplaced was 217. The mine density varied among lanes, with the number of mines per lane ranging from 0 to 21. The mine population included both antitank (AT) and antipersonnel (AP) mines with high metal (M), low metal (LM), and no metal (NM) content. AP mines were emplaced at a depth of 1 cm below ground level. AT mines were buried at a depth of either 1 or 10 cm below ground level.

The detection systems were operated by three teams of soldiers with 12B combat engineer specialization. Each test mission required a team to sweep one 1.5 m by 50 m lane. There was no restriction on the amount of time permitted per mission. When the operator of the detector concluded that a specific location potentially contained a mine-like target, that point was marked with a chip and classified as a nomination. All chip locations were then surveyed, and this information was used to evaluate each system's performance.

C. MEASURES OF PERFORMANCE

To score the system performance, marked locations were compared to the emplaced location of mines to determine detections and false alarms. A mine was deemed detected if the sensor operator made a target nomination within an allowable miss distance, referred to as a "halo." Typically, a 6-inch (15-cm) halo was used to produce the performance evaluations presented in this report. False alarms were declarations outside the halo. If more than one target marker was within the halo of an emplaced mine, the nomination nearest the mine was deemed a detection and all other nominations within the halo were considered redundant and were not counted as either detections or false alarms. For comparison of detection system performance, detection rate was broken down by mine size into AT and AP mines, and by metal content into M, LM, and NM mines.

D. PERFORMANCE

The two contractor systems exhibited similar performance to the AN/PSS-12 for AT/M, AP/M, and AP/LM. For AT/LM and AT/NM, both systems outperformed the AN/PSS-12. Finally, the CRC system exhibited a slight statistically significant improvement over the AN/PSS-12 for AP/NM, whereas the GDE system did not exhibit a statistically significant increase in performance, as determined from the upper limits on the confidence intervals calculated using a binomial detection process. Table ES-1 gives the details.

Table ES-1. Summary of Overall Performance of the Three Systems Under Test

Mine Type	GDE			CRC			AN/PSS-12		
	FAR (m^{-2})	P_d	*SNR*	*FAR* (m^{-2})	P_d	*SNR*	*FAR* (m^{-2})	P_d	*SNR*
AT/M	0.50	0.97	8.3	0.67	1.0	∞	0.56	1.0	∞
AP/M	0.50	0.97	9.2	0.67	0.93	7.9	0.56	0.97	9.1
AT/LM	0.50	0.90	6.7	0.67	0.97	7.9	0.56	0.67	3.5
AP/LM	0.50	0.66	5.1	0.67	0.69	4.9	0.56	0.67	5.0
AT/NM	0.50	0.91	6.9	0.67	0.89	6.1	0.56	0.34	−1.7
AP/NM	0.50	0.32	1.1	0.67	0.46	2.4	0.56	0.20	−1.9

Key: FAR = false-alarm rate
P_d = probability of detection
SNR = signal-to-noise ratio

E. CONCLUSIONS

- Both the GDE and CRC systems provide increased capability over the AN/PSS-12. This is particularly true with regard to the detection of AT/LM, AT/NM, and potentially for AP/NM mines. Regardless of the improved performance of the contractor systems relative to the AN/PSS-12, both performed poorly when attempting to detect AP/LM and very poorly when attempting to detect AP/NM mines
- Detection of NM mines by the AN/PSS-12—which does not have the capability to detect nonmetallic objects—indicates that visual cues may have influenced the test results.
- Probabilities of detection in the current test are somewhat lower than have been achieved by the same systems in previous tests. This may be attributable to operation of the equipment by soldiers rather than contractor personnel; it may also be due to differing clutter environments, target populations, and natural geology.

I. INTRODUCTION

A. OBJECTIVE

In March 1996, the U.S. Army Bosnia Countermine Task Force sponsored a demonstration of landmine detection systems at Fort A.P. Hill, Virginia (Andrews et al., 1996). Of the 13 systems, 9 were hand-held and 4 were vehicle-mounted. Following the test at Fort A.P. Hill, the Army selected two hand-held detection systems, one manufactured by Coleman Research Corporation (CRC), the other by GDE Systems, Inc. (GDE), to compare to the AN/PSS-12, the Army's currently fielded electromagnetic induction mine detector. A follow-on test was held at Aberdeen Proving Ground (APG), Maryland, in December 1996. The primary goal of this test was to determine whether either of the candidate systems provided increased capability over the AN/PSS-12. If an improvement in capability was documented, the detectors could be immediately deployed to Bosnia. This report compares the detection performance of these three systems, measured primarily as probability of detection and false-alarm rate. We have not considered many other important factors, including weight, ergonomics, reliability, and cost, which must ultimately influence any decision about usefulness of the equipment.

B. DESCRIPTION OF SYSTEMS

The two systems under consideration were developed by CRC and GDE. Both systems integrate a ground-penetrating radar (GPR) with an electromagnetic induction metal detector. In the CRC system, called the Drop In GPR Sensor (DIGS), a 1–3 GHz radar is added to the AN/PSS-12. The radar uses two spiral antennas, one transmit and one receive. Each is approximately 3 inches in diameter. Separate audio signals indicate detections by the GPR and the metal detector. A switch allows the operator to hear signals from the GPR, the metal detector, or both sensors. Signals from the two sensors are not integrated or fused in any way: the "both" option simply presents two distinguishable signals to the operator.

The GDE system consists of a GPR in the 0.5 to 3.0 GHz band coupled to a metal detector. The metal detector system consists of the AN/PSS-12 control and sense electronics combined with a transmit/receive coil designed by GDE. The metal detector system has similar operational characteristics to the AN/PSS-12. Separate audio signals are

presented to the operator for each of the two sensors. In addition, the GDE system incorporates a video display.

C. PRELIMINARY TESTING OF SYSTEMS

The CRC and GDE systems were selected to participate in a December 1996 test at Aberdeen, based on their performance in the A.P. Hill demonstration (Andrews et al., 1996). Several metal detectors were tested at A.P. Hill, including an "improved" version of the AN/PSS-12. The standard AN/PSS-12 was not among them. In the A.P. Hill demonstration, the aggregate detection probability, P_d, for most of the stand-alone metal detectors fell into the range 0.65 to 0.75, where the aggregate P_d includes all mine types emplaced. The aggregate detection probability is highly dependent on the distribution of mine types. Thus, each particular test will result in a characteristic P_d because of the variation in the mine-type distribution. The metal detectors generally exhibited false-alarm rates (*FAR*s) in the range 0.73–0.83 per m^2. In comparison, the GDE system (consisting of both a metal detector and a GPR) tested at Fort A.P. Hill had a probability of detection in the same range as the metal detector group (P_d = 0.74), but recorded a much lower *FAR*: 0.52 per m^2. The CRC system (also consisting of both a metal detector and a GPR) had a probability of detection (P_d = 0.83), which was higher than that of most metal detectors, and a *FAR* of 0.85 per m^2, which fell at the high end of the range experienced by metal detectors. Thus, both the CRC and GDE systems appeared to provide a potential improvement of detection capability over the stand-alone metal detector technology demonstrated at Fort A.P. Hill. To determine if this improvement was also true in comparison to the current issue AN/PSS-12, the APG test was conducted.

D. DESCRIPTION OF TEST

Eighteen 1.5 m by 50 m lanes were mined with a total of 217 landmines at surveyed locations. The number of mines per lane ranged from 0 to 21. The mine population included both antitank (AT) and antipersonnel (AP) mines with high metal (M), low metal (LM), and no metal (NM) content. Table I-1 provides a brief description of the mines used in this test, including any modifications to make the mines safe for this test.[1] Appendix B

---

1 For example, the M19 as used in this test contains approximately 0.7 g of copper and a steel firing pin with a mass of 0.2 g (see Appendix B). The total metallic content very closely approximates the actual content of a live mine. The demilitarization process may have resulted in a small loss of total metallic content, but the loss is assumed to be very small, and therefore to not affect the test. Still, as in any test where simulants are employed, care should be taken in extrapolating test performance to expectations for operational performance.

Table I-1. Description of Mines Used in Aberdeen Test*

Mine Type	Type	Diam. (cm)	Nominal Description	As-Used Description
M21	AT M	23	American conventional tilt-rod fuzed, metal-cased blast mine.	Empty metal case filled with RTV 3110 rubber. No boosters or detonators.
M12A1	AT M	33	American practice AT mine.	Empty metal casings filled with RTV 3110 rubber. No boosters or detonators.
VAL-69	AP M	10	Italian plastic case bounding fragmentation mine (metal fragment).	Empty metal case. No boosters or detonators.
PROM1	AP M	7.5	Metal case bounding fragmentation mine—former Yugoslavia.	Empty metal case. No boosters or detonators.
M19	AT LM	33	American rectangular plastic blast mine containing ~1 g metal.	Contained only detonator with approximately 0.7 g copper and 0.2 gram metallic firing pin.
TMA4	AT LM	28	Former Yugoslavian plastic-cased blast mine with low metal content.	Three demilled detonators each with 0.3 g Al alloy. Total metal 0.9 g.
VS2.2	AT LM	23	Italian plastic blast mine with low metal content.	Demilled detonator and a number of small metallic components. Total metallic mass 3.08 g.
TM62P3	AT LM	32	Former Soviet Union blast mine with plastic case; only metal is in fuze.	Detonator surrogates contained 3.8 g total metal.
TS50	AP LM	9	Italian plastic-cased cylindrical blast mine with low metal content.	Demilled detonators contained 0.3 g copper. Additional small metallic components. Total metallic mass 4.59 g.
VS50	AP LM	9	Italian round plastic-cased blast mine. Pressure plate is reinforced with metal.	Demilled detonators contained 0.3 g metal. Additional metallic components and metal reinforced pressure plate included. Total metallic mass 18.43 g.
PMA3	AP LM	10	Former Yugoslavian plastic-/rubber-cased blast mine with chemical fuze.	Demilled detonator contains 0.3 g Al alloy and small steel spring (weight unknown). Total metallic mass 0.5 g.
EM12	AT NM	30.5	NVESD nonmetallic surrogate.	Filled with RTV 3110.
EM6	AT NM	15	NVESD nonmetallic surrogate.	Filled with RTV 3110.
EM3	AP NM	7.5	NVESD nonmetallic surrogate.	Filled with RTV 3110.

* See Appendix B for photograph and more complete description of each mine and mine surrogate

has a more complete listing, with descriptions. Table I-2 lists the number of each type of mine emplaced in the lanes. All the mines were emplaced at depths consistent with current doctrine (Morris, 1997). AP mines were emplaced at a depth of 1 cm below ground level. AT mines were buried at a depth of either 1 or 10 cm below ground level.

Table I-2. Mine Emplacement for Aberdeen Test

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**2**
M12A1	0	1	0	0	0	0	0	0	3	0	0	1	1	1	0	0	2	0	**9**
Subtotal	*0*	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*0*	*1*	*1*	*1*	*1*	*0*	*0*	*2*	*0*	***11***
AP/M																			
VAL-69	0	3	0	0	0	0	0	2	6	0	0	1	0	2	0	0	2	1	**17**
PROM1	0	0	1	0	0	0	3	2	2	0	1	0	0	0	0	0	0	0	**9**
Subtotal	*0*	*3*	*1*	*0*	*0*	*0*	*3*	*4*	*8*	*0*	*1*	*1*	*0*	*2*	*0*	*0*	*2*	*1*	***26***
AT/LM																			
M19	1	1	0	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	**6**
TMA4	0	0	1	0	0	3	0	0	0	0	0	0	0	0	2	0	1	0	**7**
VS2.2	1	2	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	**6**
TM62P3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	1	**5**
Subtotal	*2*	*3*	*1*	*0*	*0*	*5*	*2*	*1*	*0*	*0*	*1*	*1*	*1*	*0*	*4*	*0*	*2*	*1*	***24***
AP/LM																			
TS50	2	4	4	0	0	5	0	2	0	0	0	6	4	3	6	0	0	0	**36**
VS50	0	3	4	0	0	5	0	3	0	0	0	4	5	3	4	0	4	1	**36**
PMA3	0	4	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	**10**
Subtotal	*2*	*11*	*8*	*0*	*0*	*14*	*2*	*5*	*0*	*0*	*0*	*10*	*9*	*6*	*10*	*0*	*4*	*1*	***82***
AT/NM																			
EM12	0	0	0	2	0	0	2	0	0	6	0	2	4	2	0	9	0	0	**27**
EM6	0	0	0	0	0	0	1	2	0	3	1	0	0	2	0	7	3	0	**19**
Subtotal	*0*	*0*	*0*	*2*	*0*	*0*	*3*	*2*	*0*	*9*	*1*	*2*	*4*	*4*	*0*	*16*	*3*	*0*	***46***
AP/NM																			
EM3	0	2	3	2	0	0	0	2	0	4	0	0	5	2	0	5	1	2	**28**
Subtotal	*0*	*2*	*3*	*2*	*0*	*0*	*0*	*2*	*0*	*4*	*0*	*0*	*5*	*2*	*0*	*5*	*1*	*2*	***28***
Total	**4**	**21**	**13**	**4**	**0**	**19**	**10**	**14**	**11**	**13**	**4**	**15**	**20**	**15**	**14**	**21**	**14**	**5**	**217**

The detection systems were operated by three teams of soldiers with 12B combat engineer specialization. The teams were designated X, Y, and Z. Teams Y and Z each consisted of the same two soldiers throughout the test. Three different soldiers were members of team X, and during the test, these three soldiers traded in and out of the two

active slots on the team. Each test mission required a team to sweep one 1.5 m by 50 m lane. Soldiers were teamed to ensure that no individual soldier would be required to search more than 1.5 m by 25 m at any one time. There was no restriction on the amount of time permitted per mission. Rather, the time required was recorded to assess differences in scan rate (sometimes called rate of advance). When the detector operator concluded that a specific location potentially contained a mine-like target, that point was marked with a chip. All chip locations were then surveyed and compared to the emplaced location of mines to determine detections and false alarms.

If there were no time restrictions on the test, the optimal design would have had all three operator teams visit all 18 lanes with all three detector systems. In fact, the time available for the test, including training the soldiers on the operation of the CRC and GDE systems, was limited to 3 work weeks. In this time each team visited 16 lanes. But only 12 lanes were swept by all three soldier teams operating all three detection systems. The other six lanes were visited as resources allowed, with two team/detector combinations visiting each lane. Each team/detector combination encountered between 188 and 199 mines, with each detector system encountering nearly 600 total mine targets.

II. DATA

A. P_d AND *FAR*

The primary measures of detection performance are the probability of detection (P_d) and the false-alarm rate (*FAR*). P_d is defined as the number of mines detected divided by the number of emplaced mines. *FAR* is defined as the number of false alarms per square meter. A mine is deemed detected if the sensor operator has made a target nomination within an allowable miss distance, referred to as a "halo." The scores reported throughout this document all use an operationally dictated 6-inch (15-cm) halo unless otherwise indicated. False alarms are declarations outside the halo. If more than one target nomination is placed within the halo of an emplaced mine, the nomination nearest the mine is deemed a detection and all other nominations within the halo are considered redundant and are not counted as either detections or false alarms. These three situations are depicted in Figure II-1.

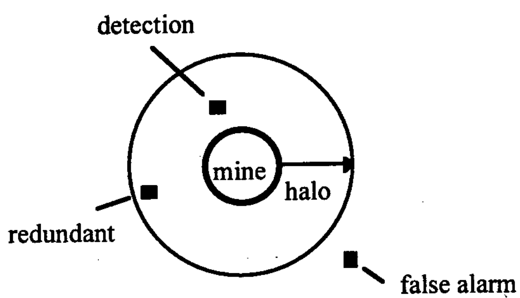


Figure II-1. A Target Nomination within the Halo Is Scored as a Detection

For comparison of detection system performance, P_d is broken down by mine size into AT and AP mines, and by metal content into M, LM, and NM mines. Thus, P_d is reported for AT/M, AP/M, AT/LM, AP/LM, AT/NM, and AP/NM. Table II-1 shows the summary of P_d and *FAR* calculated using all encounters of emplaced mines by all operators in all lanes visited. Tables II-2, II-3, and II-4 show the same results broken down by operator team. These tables provide the data necessary to compute many parameters of interest, including the variability of performance among the operator teams using the same detectors.

Table II-1. Summary of P_d with Confidence Interval (Section III.A) and *FAR*, All Encounters by All Teams

Mine Type	GDE			CRC			AN/PSS-12		
	FAR (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.
AT/M	0.50	0.97 (0.86–1.00)	32/33	0.67	1.0 (0.91–1.00)	33/33	0.56	1.0 (0.91–1.00)	33/33
AP/M	0.50	0.97 (0.91–1.00)	69/71	0.67	0.93 (0.86–0.97)	66/71	0.56	0.97 (0.91–1.00)	69/71
AT/LM	0.50	0.90 (0.81–0.96)	54/60	0.67	0.97 (0.90–0.99)	58/60	0.56	0.67 (0.55–0.77)	40/60
AP/LM	0.50	0.66 (0.60–0.71)	141/215	0.67	0.69 (0.64–0.75)	149/215	0.56	0.67 (0.62–0.73)	145/215
AT/NM	0.50	0.91 (0.85–0.95)	111/122	0.67	0.89 (0.83–0.93)	108/122	0.56	0.34 (0.27–0.41)	41/122
AP/NM	0.50	0.32 (0.23–0.41)	24/76	0.67	0.46 (0.36–0.56)	35/76	0.56	0.20 (0.13–0.29)	15/76

Table II-2. Summary of P_d and *FAR* for Team X

Mine Type	GDE			CRC			AN/PSS-12		
	FAR (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.
AT/M	0.42	0.91	10/11	0.48	1.0	11/11	0.48	1.0	11/11
AP/M	0.42	1.0	22/22	0.48	1.0	26/26	0.48	1.0	23/23
AT/LM	0.42	0.87	20/23	0.48	0.95	19/20	0.48	0.47	8/17
AP/LM	0.42	0.60	46/77	0.48	0.65	47/72	0.48	0.61	40/66
AT/NM	0.42	0.88	37/42	0.48	0.89	33/37	0.48	0.26	11/43
AP/NM	0.42	0.21	5/24	0.48	0.50	12/24	0.48	0.11	3/28

Table II-3. Summary of P_d and *FAR* for Team Y

Mine Type	GDE			CRC			AN/PSS-12		
	FAR (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc
AT/M	0.54	1.0	11/11	0.80	1.0	11/11	0.64	1.0	11/11
AP/M	0.54	0.96	25/26	0.80	0.87	20/23	0.64	0.91	20/22
AT/LM	0.54	0.95	19/20	0.80	0.94	16/17	0.64	0.65	15/23
AP/LM	0.54	0.63	45/72	0.80	0.68	45/66	0.64	0.66	51/77
AT/NM	0.54	0.95	35/37	0.80	0.88	38/43	0.64	0.29	12/42
AP/NM	0.54	0.38	9/24	0.80	0.46	13/28	0.64	0.21	5/24

Table II-4. Summary of P_d and *FAR* for Team Z

Mine Type	GDE			CRC			AN/PSS-12		
	FAR (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.
AT/M	0.54	1.0	11/11	0.75	1.0	11/11	0.57	1.0	11/11
AP/M	0.54	0.96	22/23	0.75	0.91	20/22	0.57	1.0	26/26
AT/LM	0.54	0.88	15/17	0.75	1.0	23/23	0.57	0.85	17/20
AP/LM	0.54	0.76	50/66	0.75	0.74	57/77	0.57	0.75	54/72
AT/NM	0.54	0.91	39/43	0.75	0.88	37/42	0.57	0.49	18/37
AP/NM	0.54	0.36	10/28	0.75	0.42	10/24	0.57	0.29	7/24

For these results, shown in Tables II-1, II-2–II-4, all encounters of emplaced mines are used in the computation of P_d, and all lanes visited are used in the computation of *FAR* (as opposed to using only the common 12 lanes visited by all three operator teams using each of the three detector systems). The use of *all* mine encounters to calculate both P_d and *FAR* ensures the maximum statistical certainty of the these performance measures. To ensure that including mine lanes not surveyed by *all* teams with *all* systems does not bias the results, we calculated the cumulative performance of each system on the 12 common surveyed mine lanes (lanes 1–3, 5, 9, 11–14, and 16–18). Table II-5 shows the results. All but two P_ds are within a few percentage point of the P_ds reported in Table II-1. The two P_ds that differ by more than just a few percentage points are for the AN/PSS12 on AT/LM and AP/LM. A comparison between the two approaches is shown in Figure II-2. Still, the P_ds for the full data set are within the 90-percent confidence intervals for all P_ds for the common data set (see Section III.A for description of confidence intervals). Hence, for computation of P_d, all encounters are legitimate data points, whether or not the mine was encountered by all possible detector/operator combinations. For computation of *FAR*, there is likely to be some variability in the clutter environment from lane to lane. However, since no clutter was deliberately emplaced, this represents true variability in the anthropic and natural clutter environments, and because of the proximity of the lanes, such variability should be minimal. Table II-5 shows that only the CRC system exhibits a change in *FAR* greater than 1 or 2 percent. For the CRC system the *FAR* decreases by approximately 6 percent if one uses only the 12 lanes common to all sensors.

Table II-5. Summary of P_d with Confidence Interval (Section III.A) and *FAR*, the Twelve Common Lanes Surveyed by Each Team

Mine Type	GDE			CRC			AN/PSS-12		
	FAR (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.	*FAR* (m^{-2})	P_d	#det./ #enc.
AT/M	0.49	0.97 (0.86–1.00)	32/33	0.63	1.0 (0.91–1.00)	33/33	0.57	1.0 (0.91–1.00)	33/33
AP/M	0.49	0.97 (0.89–0.99)	55/57	0.63	0.91 (0.82–0.97)	52/57	0.57	0.97 (0.89–0.99)	55/57
AT/LM	0.49	0.89 (0.76–0.96)	32/36	0.63	0.97 (0.87–1.00)	35/36	0.57	0.75 (0.60–0.86)	27/36
AP/LM	0.49	0.65 (0.58–0.71)	99/153	0.63	0.67 (0.61–0.74)	103/153	0.57	0.73 (0.66–0.78)	111/153
AT/NM	0.49	0.91 (0.85–0.96)	82/90	0.63	0.87 (0.79–0.92)	78/90	0.57	0.37 (0.28–0.46)	33/90
AP/NM	0.49	0.30 (0.20–0.41)	18/60	0.63	0.48 (0.37–0.60)	29/60	0.57	0.23 (0.15–0.34)	14/60

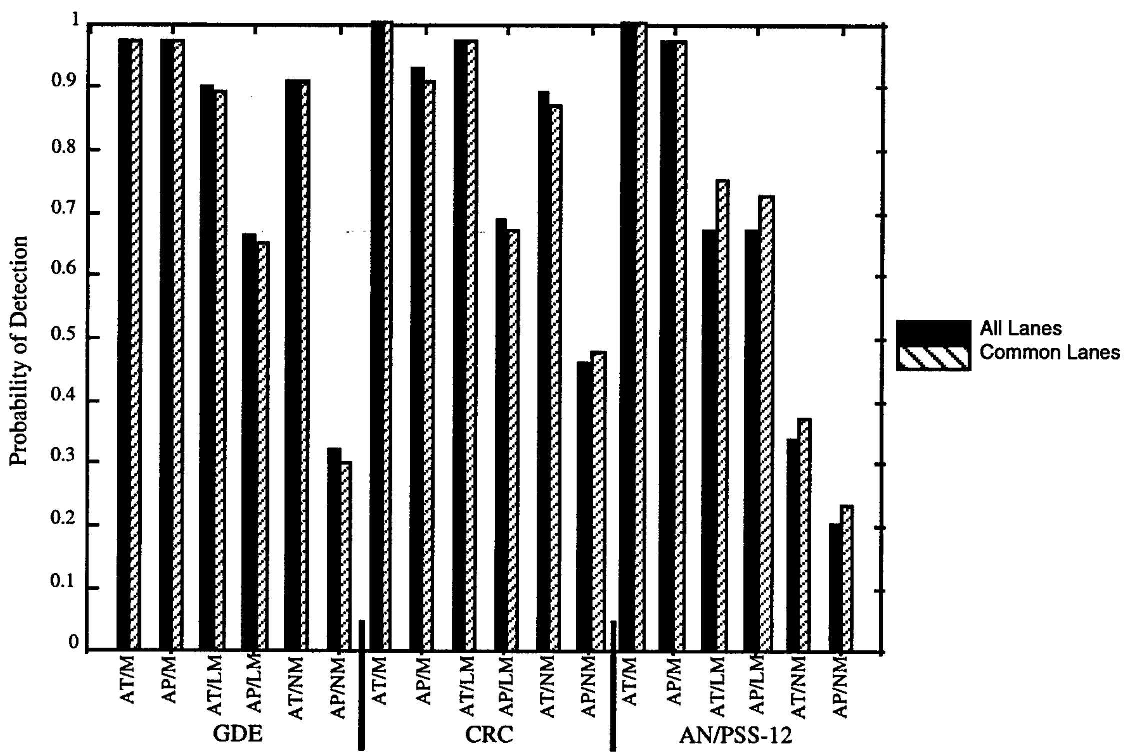


Figure II-2. Comparison of the Probability of Detection for the 12 Common Lanes Visited by All Teams with P_d for All Lanes Visited by All Teams

Appendix A contains a run-by-run and lane-by-lane breakdown of the mines found by each operator team using each detector system, as well as summaries of operator/detector performance by specific mine type and classification.

B. DATA DISCREPANCIES

It should be noted that both P_ds and *FAR*s reported here differ slightly from the values reported in the TECOM Report, "Final Report for the Technical Feasibility Test (TFT) of the Bosnia Handheld Mine Detection System (BOSHMIDS)" (Morris, 1997). These differences are a result of the use of the raw electronic survey data and the Institute for Defense Analyses Mine Target Matching Algorithm (IDAMTMA) and computer code instead of the spreadsheet data provided by TECOM. The IDAMTMA and associated computer code provides a robust test analysis package.

Using the IDAMTMA showed that two mines listed by the test survey crew as detected were actually not detected (did not fall within the 15-cm "halo"), and one mine listed as not detected was actually detected. These detection changes were verified by an independent mine target matching computer code. The specific detection discrepancies are

1. GDE, Team Z on lane 16—mine 1607 is a miss not a detection.
2. CRC, Team X on lane 9—mine 904 is a detection not a miss.
3. CRC, Team Y on lane 4—mine 400 is a miss not a detection.

The result of these detection differences are slight and do not alter the conclusion of the TECOM Report.

Table II-6 lists the number of false alarms used in this analysis and also the original values used in the TECOM report. The change in the number of false alarms is a result of differences between the number of alarms recorded in the electronic survey data and the number of alarms reported in the TECOM report. In addition, several false alarms were eliminated because they are actually redundant detections. After accounting for these changes, the total number of false alarms for the GDE system, CRC system, and the AN/PSS-12 increase by 4, 10, and 5, respectively. Finally, the false-alarm data resulting from the 12 December 1996 collection by Team X using the AN/PSS-12 on lane 8 and Team Y using the AN/PSS-12 on lane 8 is reversed.

There are a number of other differences between the data used in this analysis and the TECOM report. It appears that team information was transcribed incorrectly five times, based on the assumption that each team visits a lane once with a specific system. Although these discrepancies slightly affect each team's performance with two contractor systems, they do not affect the cumulative performance of the contractor systems. Table II-7 lists the corrections.

Table II-6. Revisions in the Number of False Alarms

Detection System	Team	Lane Number	Original Number of False Alarms	Revised Number of False Alarms
GDE*	Z	16	41	43
GDE	Y	17	32	33
GDE	Z	18	60	61
CRC	Y	1	64	65
CRC	Y	2	53	55
CRC	Z	3	64	65
CRC*	Y	4	78	80
CRC	X	4	48	49
CRC	X	6	22	23
CRC	Z	7	45	46
CRC*	X	9	26	25
CRC	X	14	40	41
AN/PSS-12	X	1	66	67
AN/PSS-12	Z	1	71	72
AN/PSS-12	X	2	45	46
AN/PSS-12	Z	4	61	62
AN/PSS-12	X	15	57	58

* The number of false alarms include the changes in the numbers of detections described earlier

Table II-7. Changes in Team Attributed with Lane Results

Date	Detection System	Lane Number	Original Team	Revised Team
17 Dec. 96	GDE	6	Y	X
10 Dec. 96	CRC	18	Z	Y
10 Dec. 96	CRC	12	Y	Z
10 Dec. 96	AN/PSS-12	3	Z	Y
10 Dec. 96	AN/PSS-12	1	Y	Z

III. ANALYSIS

A. STATISTICAL UNCERTAINTIES

P_d and *FAR* are by nature statistical measures. The confidence to which they are determined will depend on the size of the populations measured. For this test, error bars are calculated for probability of detection using a binomial distribution and then determining the 90-percent confidence interval (Bevington, 1969). This simple estimation of a confidence interval is an attempt to find an upper bound for the uncertainty of the single-point detection rates. Although the assumption that mine detection is a binomial process is a very crude approximation to the real detection statistics, we feel that it provides an upper limit to the magnitude of the statistical uncertainty. To determine the confidence interval, binomial probabilities were calculated for the likelihood of detecting X mines out of N opportunities for each population of interest (see Figure III-1). The lower and upper

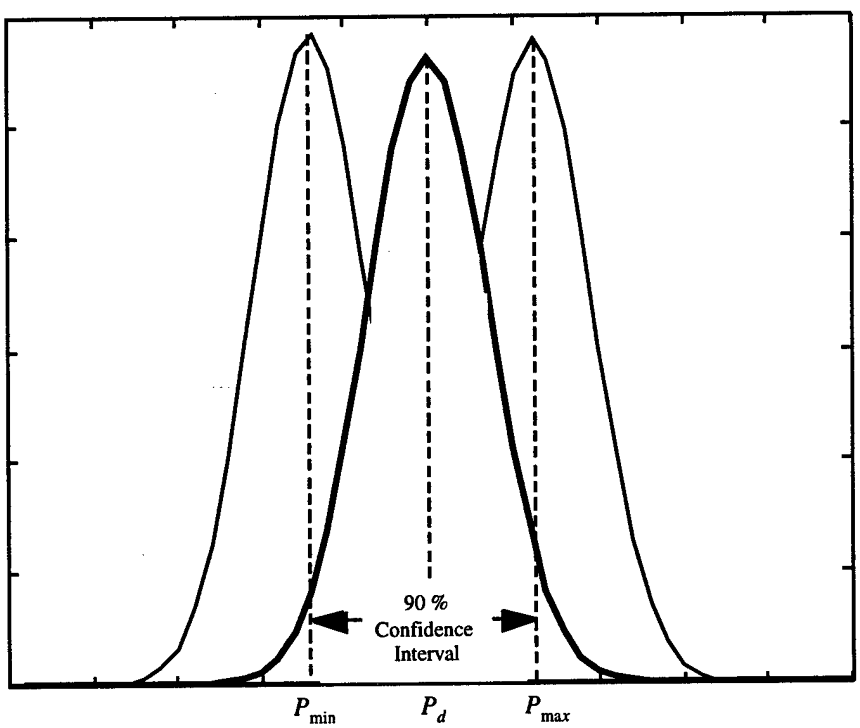


Figure III-1. Binomial Distribution Model for Upper Bound of the Confidence Interval for Probability of Detection

bounds are determined iteratively, such that the binomial distribution for each bound contains the measured P_d within its 90-percent confidence interval. If the confidence intervals overlap, there is no statistically significant difference between the two measurements at the indicated confidence level. If they are separated, then one system performed "better" than the other.

Uncertainties are calculated only for the probability of detection, and we strived to include a sufficient number of encounters to provide statistical confidence in the determination of P_d. But when the mines are divided into the six categories by size and metal content, the uncertainties for this subset of probabilities of detection increase substantially. This is seen in the probability of detection results presented in this chapter.

The same is not true for the determination of the false-alarm rate or the probability of false alarm. For example, each mine-sized patch of ground plus halo (~0.1 m^2 for a typical AP mine) is deemed an opportunity for a false alarm:[2] the detector may either alarm or pass over it without responding. For three passes with a detector system (one for each operator team) over sixteen 1.5 m by 50 m lanes, there are approximately 36,000 opportunities for a false alarm (analogous to encounters in determining P_d). The systems in this test reported fewer than 3,000 false alarms for all passes of all lanes visited. The resulting uncertainty is less than ± 0.3 percent in N_{fa}, compared to uncertainties of up to 10 percent in P_d. If the larger AT mine diameter (~0.33 m) is used instead of that of the AP mine, then the potential number of false alarms encountered drops by almost a factor of 3, and the uncertainty remains smaller than ±1.0 percent. The false-alarm rate is therefore statistically well determined for this site. It should be noted that the false-alarm rates determined in this test cannot be used to predict the number of false alarms expected at other sites because the site-to-site clutter variability will be the greatest contributor to the reproducibility of this quantity. It has been shown that clutter variation, and thus false-alarm rate variation, over multiple sites can exceed a factor of 10 (Altshuler et al., 1997).

Table III-1 shows the 90-percent confidence intervals for probability of detection which is based on a binomial distribution. The calculation of these intervals is discussed in Andrews et al. (1996).

---

2 A mine-sized patch of ground plus the surrounding halo is called the mine-detection area. This mine-detection area is dependent on the diameter of the mine as well as the halo used to determine detections. The diameter of AP mines and mine surrogates used in this test range from 7.5 to 10 cm. The resulting AP detection areas range from 0.11 m^2 to 0.13 m^2, assuming a 15-cm halo. The diameter of AT mines and mine surrogates used in this demonstration range from 15 to 33 cm. The resulting AT detection areas range from 0.16 m^2 to 0.31 m^2, assuming a 15-cm halo.

Table III-1. Summary of P_d Calculated Using All Encounters by All Operators, and Including Uncertainties at 90-percent Confidence Level

Type	GDE		CRC		AN/PSS-12	
	P_d	#detections/ #encounters	P_d	#detections/ #encounters	P_d	#detections/ #encounters
AT/M	0.97 (0.864–0.999)	32/33	1.00 (0.913–1.00)+	33/33	1.00 (0.913–1.00)+	33/33
AP/M	0.972 (0.914–0.996)	69/71	0.930 (0.853–0.973)	66/71	0.972 (0.914–0.996)	69/71
AT/LM	0.90 (0.812–0.956)	54/60	0.967 (0.899–0.995)	58/60	0.667 (0.553–0.768)	40/60
AP/LM	0.656 (0.598–0.71)	141/215	0.693 (0.637–0.745)	149/215	0.674 (0.617–0.727)	145/215
AT/NM	0.910 (0.855–0.949)	111/122	0.885 (0.826–0.930)	108/122	0.336 (0.265–0.413)	41/122
AP/NM	0.316 (0.228–0.415)	24/76	0.461 (0.362–0.562)	35/76	0.197 (0.125–0.288)	15/76

+ For a P_d of 1.00, the lower confidence interval is still calculated using a binomial distribution with 95 percent below the measured P_d. This does not result in a 90-percent confidence interval for P_d, but does provide a comparative measure of the lower limit of the probability of detection.

B. *SNR* CALCULATIONS

P_d and *FAR* are not independent variables. For a given sensor, P_d can be changed by lowering or raising the threshold for declaring a target nomination. This change in threshold results in an associated change in the number of false alarms, e.g., for a decrease in threshold, both the detection and false-alarm rates increase. If two sensors are operated at different thresholds, it is difficult to compare their merits on the basis of separate measures of P_d and *FAR*. For example, given two identical sensors with different thresholds, very different P_ds and *FAR*s are possible. By evaluating performance using only P_d, the sensor with the higher P_d is classified as superior, when in actuality its performance is identical to the other sensor. If, on the other hand, two different sensors set at different relative thresholds are used, P_ds might be very similar with very different *FAR*s. Thus, the relative capabilities of the two systems are incorrectly determined by using P_d only. Therefore, it is critical to develop metrics which permit a more accurate assessment of the true sensor performance.

Even when the *FAR* is included, a meaningful comparison is often difficult. To facilitate comparison of the contractor system performance on a single site (here all 18 mine lanes), some means to functionally link P_d and *FAR* in a single measure is required. Prior IDA work on detection tests (Andrews et al., 1996; Altshuler et al., 1995) has used a performance measure based on the Receiver Operator Characteristic (ROC) curve approach.

The goal of this approach is to establish a measure of performance by modeling the dependence of probability of detection on the false-alarm rate. The ROC model is used to generate unique curves of constant performance. The location of any point on a single curve is dependent on the sensor threshold. If one assumes that the mine detection tests provide sensor performance at a single threshold, relative performance of different sensors is based on the ROC model. When applying this assumption to an operational field test, one must be careful, because the user tends to adjust the gain during the testing process, therefore changing the apparent threshold. In addition, the apparent threshold varies because the final decision process is set by the human visual and/or auditory response to sensor. The assumption here is that one may average the apparent threshold over the set of mines and potential false alarms encountered in the field, and produce a meaningful ROC model to evaluate performance. To determine relative performance, a single point representing the probability of detection versus the probability of false alarm[3] for each sensor is plotted. Probability of false alarm is used instead of *FAR* to provide a consistent link to the statistical performance models employed. The relative performance of different sensors is then determined by assuming a Gaussian model for the distribution function of the response of the sensor to noise/clutter and mines. This approach results in a single relative performance measure "*d*," described by Van Trees (1968) for each sensor.

The weakness of this approach is the approximation of the distribution functions of both the response of the sensor to noise/clutter and mines as Gaussian. The Gaussian model is valuable as a surrogate distribution function, especially when the signal-to-clutter ratio is small (accurate for this and most mine detection tests). When the signal-to-clutter ratio is small, the performance is dominated by the central region of the distribution function. When the signal-to-clutter ratio is large, the tails of the distribution functions dominate and the Gaussian model fails (Altshuler et al., 1997). Even in the case of small signal-to-clutter ratio, the Gaussian model is not ideal and other approaches to establishing a single metric of performance may be better.

To address concerns about distribution functions, we borrow a different measure of performance, the signal-to-noise ratio (*SNR*) as described by Blake (1986) and others. This approach is similar to that of Van Trees (1968), except that it assumes that the function that describes the noise (and clutter) measured at the output of the sensor is a Rayleigh distribution (Minkler and Minkler, 1990), not a Gaussian distribution. The two approaches

---

3 Probability of false alarm is a measure of the number of false alarms relative to the opportunities for false alarms.

are similar and consistent, but cannot be compared directly. It is most probable that the actual distribution function is neither Gaussian nor Rayleigh, and might be better described by a log-normal or Weibull distribution function. But for this test, the Rayleigh distribution provides a method for performance comparison.

To derive the performance measure, the signal and noise populations are represented by two Gaussian random variables added in quadrature, also called a Rayleigh distribution (for the radar application, the random variables correspond to in-phase and quadrature contributions). This is a reasonable model for noise-limited radar detection; however, it may not be a good representation of clutter-limited performance of mine detectors. Nonetheless, the formalism gives a single, well-documented method to compare performance in the same test, while accounting for different threshold settings.

To calculate the *SNR* for different contractor systems and mine types, the Rayleigh distribution functions which result in the measured P_d and calculated P_{fa} are required. The probability density function for the measured sensor response R when a mine is present is given by

$$f_{sn}(R) = \frac{R}{\sigma^2}\exp\left\{\frac{-\left(R^2+a^2\right)}{2\sigma^2}\right\}I_o\left(\frac{aR}{\sigma^2}\right),$$

where σ is the standard deviation of the noise distribution, a is the amplitude of the signal caused by the mine, and I_0 is first-order modified Bessel function with imaginary argument. The Bessel function is present to acount for correlation between the two Gaussian random variables (Rice, 1945). If there is no mine, a is zero and the clutter signal is given by

$$f_c(R)=\frac{R}{\sigma^2}\exp\left\{\frac{-R^2}{2\sigma^2}\right\}.$$

One may now determine P_{fa} and P_d, using the two distribution functions given above. These are given by

$$P_{fa} = \int_T^\infty f_c(R)dR,$$

$$P_d = \int_T^\infty f_{sn}(R)dR,$$

where T is the threshold. P_{fa} can be solved for analytically:

$$P_{fa} = \exp\left\{\frac{-T^2}{2\sigma^2}\right\}.$$

At a given threshold the signal-to noise ratio is given by

$$SNR = \frac{a^2}{2\,\sigma^2}\ .$$

Since the threshold is an unknown quantity, but P_{fa} is measured, the threshold can be written as a function of P_{fa}. In addition, by using two change of variables,

$$\tilde{a} = \frac{a}{\sigma} \text{ and } \tilde{R} = \frac{R}{\sigma},$$

it is possible to write an expression for probability of detection:

$$\int_{\left(-2\ln\left(P_{fa}\right)\right)^{1/2}}^{\infty} \tilde{R}\exp\left\{\frac{-\left(\tilde{R}^2 + \tilde{a}^2\right)}{2}\right\} I_o\left(\tilde{a}\tilde{R}\right)d\tilde{R}.$$

This equation can be solved numerically for a given P_{fa} to generate P_d versus *SNR* curves for a constant false-alarm rate, where

$$SNR = \frac{\tilde{a}^2}{2}.$$

The curves are unique for a given P_{fa}, and thus the resulting signal-to-noise ratio determined for a given P_{fa} and P_d is a unique measure of the system performance at that specific test site. This *SNR* permits us to evaluate performance in a manner similar to the isoperformance curves used in previous analyses (Altshuler et al., 1995; Anne Andrews et al., 1996). It should be noted that this model is not useful for quantitative comparison among tests due to changes in both the target sets and the clutter distributions.

First, note that the model requires P_{fa} rather than *FAR*, which is the measured quantity. As in previous tests, we use the fraction of area covered by false alarm declarations as a surrogate for P_{fa}.[4] To calculate the areal coverage, a characteristic false alarm area must be determined. As discussed in Chapter II, each mine has a detection area (projected on the ground) that is dependent on the mine diameter and the *halo* size used in the evaluation of detection rates. The area associated with a false alarm is not well defined because the false alarm does not have a known size. To estimate the characteristic size of the false alarm, IDA uses the average mine detection area as the false alarm area. This is justified because in an operational sense, the average mine detection area defines an area which must be examined by other methods to determine if the declared anomaly is a mine

---

4 The goal of this areal measure is to provide a means to estimate the opportunities for false alarms.

or a false alarm. Using this areal surrogate for the false alarm area, the area of a single declaration is calculated as the average area covered by a mine plus the halo,

$$A_{dec} = \pi\left(\overline{R_{\text{mine}}} + \text{halo}\right)^2.$$

The fraction of the site covered by false alarms, used as a surrogate for P_{fa}, is then calculated as the number of false alarms (N_{fa}) times the area of a single declaration (A_{dec}) divided by the total area of the site where there is an opportunity for a false alarm (A_{site_fa}).

$$P_{fa} = \frac{N_{fa}}{\left(\frac{A_{site\_fa}}{A_{dec}}\right)}.$$

Since within a halo radius of a mine there is no "operational" opportunity for a false alarm, the total area of the site must be reduced by the total area occupied by all the mines and their associated halos

$$A_{site\_fa} = \left(A_{site} - \sum < A_{dec} >\right).$$

For example, the probability of false alarm for Team X on Lane 1 with the AN/PSS-12 is calculated as follows. The lane area is 75 m^2. There are two AT and two AP mines in the lane with an average area, A_{dec} (including *halo*) of 0.30 m^2 and 0.12 m^2 for the AT and AP mines, respectively.[5] The total area covered by the mines and the halos is 0.85 m^2. Therefore, the area of the site that provides an opportunity for false alarms is 74.15 m^2. If one considers AP mines to define a characteristic size and uses the 67 false alarms reported by Team X, P_{fa} is calculated to be 0.11. For an AT mine area, P_{fa} is 0.27.

It should be noted that AT and AP mines are very different in size. Therefore, we calculate P_{fa} separately for AT and AP mines using the site-averaged AT or AP mine areas. It is possible to use the average mine size and calculate a single P_{fa} for AT and AP mines together, but this does not produce as true an estimate of *SNR*. Table III-2 shows the P_{fa} values calculated as above. Values of *SNR* and P_d are calculated for each P_{fa} presented in Table III-2. Figure III-2 shows the *SNR* vs. P_d for each P_{fa}. The *SNR*s are listed in Table III-3. Ninety-percent confidence intervals calculated using the binomial hypothesis are shown in parentheses. Figure III-3 shows the *SNR* for AT/LM, AP/LM, AT/NM, and AP/NM. No attempt was made to evaluate uncertainties in P_{fa} or their effect on *SNR*.

---

5 The areas used for both the AT and AP mines are the average areas for these two classes (including the 15-cm *halo*) over all the mines emplaced for the Aberdeen test. For the entire set of lanes used in this test, A_{dec} = 0.25 m^2 for the AT mines and 0.12 m^2 for the AP mines.

Table III-2. *FAR*, P_{fa}(AT) and P_{fa}(AP) Values

	FAR	P_{fa}(AT)	P_{fa}(AP)
GDE	0.50	0.131	0.061
CRC	0.67	0.176	0.082
AN/PSS-12	0.56	0.147	0.068

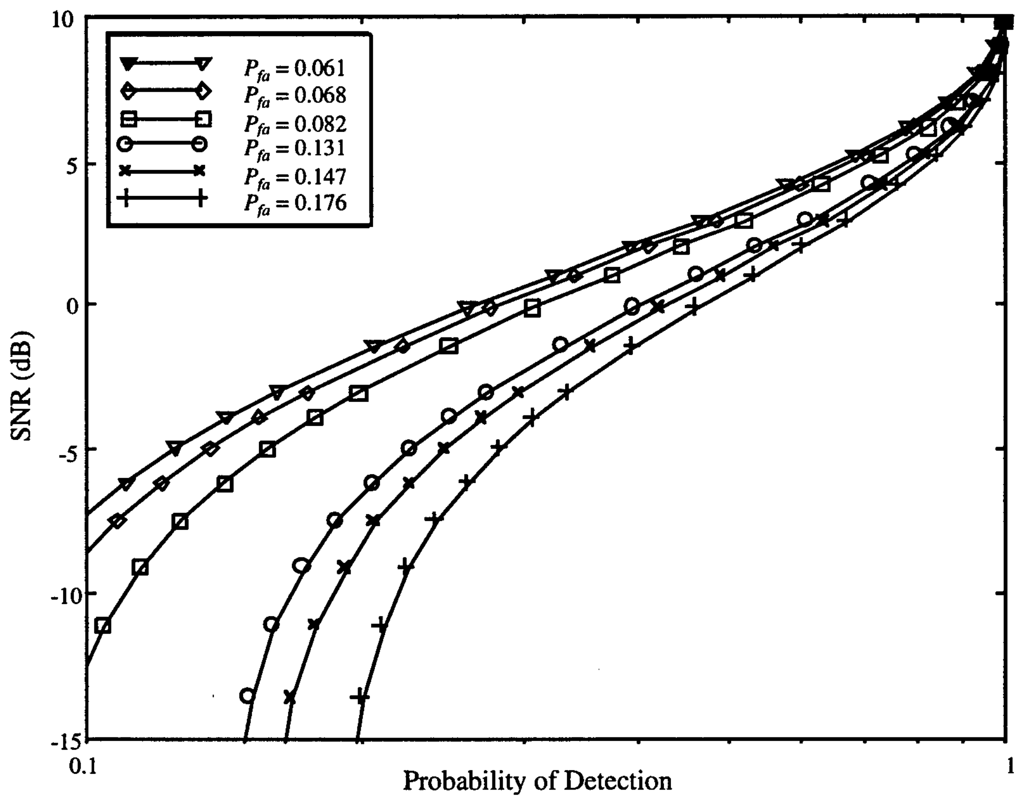


Figure III-2. Signal-to-Noise Ratio (dB) vs. P_d for P_{fa} Values Recorded at Aberdeen Test

Table III-3. Signal-to-Noise Ratios (dB)

Mine Type	AN/PSS-12	GDE	CRC
AT/M	∞* (6.7 to ∞*)	8.3 (6.1 to 10.7)	∞* (6.4 to ∞*)
AP/M	9.1 (7.8 to 10.6)	9.2 (7.9 to 10.6)	7.9 (6.8 to 8.9)
AT/LM	3.5 (2.0 to 4.7)	6.7 (5.4 to 8.0)	7.9 (6.2 to 9.4)
AP/LM	5.0 (4.5 to 5.6)	5.1 (4.5 to 5.6)	4.9 (4.4 to 5.6)
AT/NM	–1.7 (–3.8 to –0.2)	6.9 (6.0 to 7.7)	6.1 (5.2 to 6.8)
AP/NM	–1.9 (–5.3 to– 0.3)	1.1 (–0.7 to 2.4)	2.4 (1.0 to 3.6)

* A point for which $P_d = 1.0$. In this situation, SNR becomes infinite.

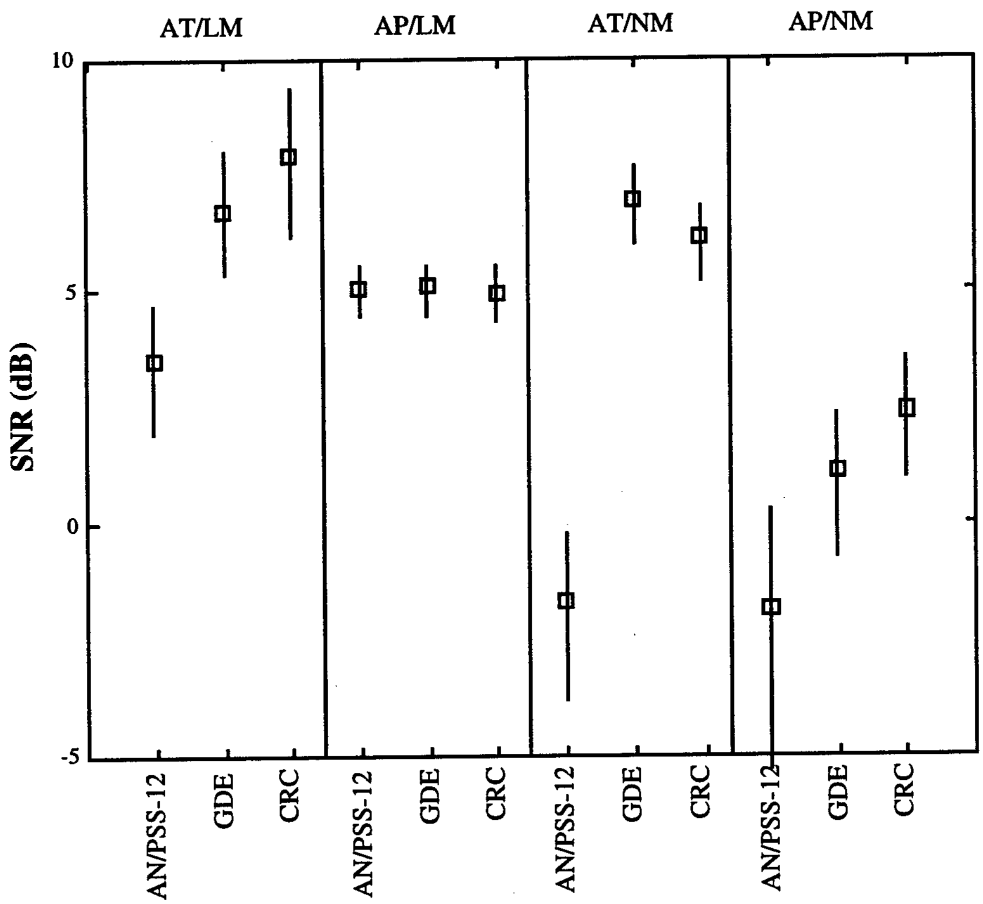


Figure III-3. Signal-to-Noise Values for Detection of AT/LM, AP/LM, AT/NM, and AP/NM Mines. Boxes represent the value calculated for the calculated P_d. Vertical lines show 90-percent confidence interval for SNR.

As noted earlier, the Rayleigh distribution and the *SNR* should be monotonically related to the Gaussian distribution approach used previously by IDA. Figure III-4 shows the Van Tree "*d*" [6] value calculated using the Gaussian distributions plotted versus the *SNR* calculated using the Rayleigh distributions. The first plot shows a linear fit to the data. Here the linear correlation coefficient is 0.9785. The second plot show a quadratic fit to the data. The goodness of correlation between the two approaches suggests that the use of the Rayleigh model as a potentially more accurate representation of the mine signature and clutter/noise distribution functions does not alter conclusions based on the earlier approach. The goodness of the quadratic fit suggests that the Gaussian approach overpredicts the performance for large "*d*." This could be a result of inaccuracies in the estimation of the tails of the distribution functions. The tails dominate the performance for large *SNR* or "*d*."

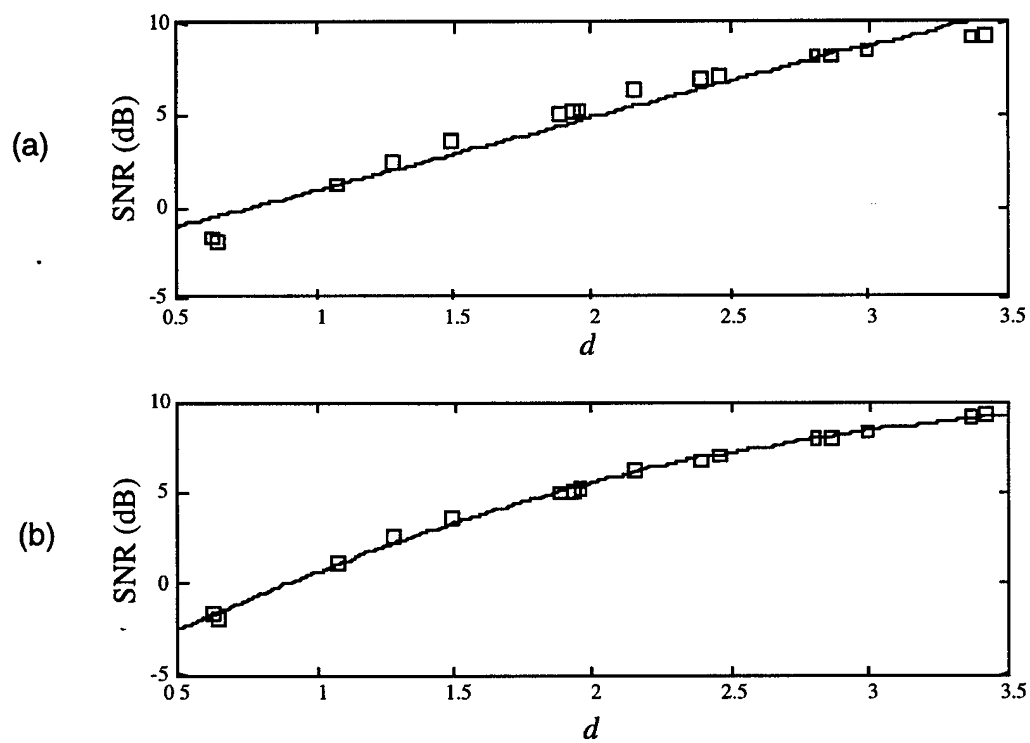


Figure III-4. Comparison on the Performance Measure "*d*" Calculated Using the Gaussian Model and the *SNR* from the Rayleigh Distribution Model for All Systems and Mine Types Except AT/M for the AN/PSS-12 and CRC System. (a) A linear fit to the data with correlation coefficient of 0.9885. (b) A quadratic fit to the data.

---

6 "*d*" is a measure of the separation of the clutter/noise distribution function and the combined clutter/noise and signature distribution function.

C. EVALUATION OF DETECTOR PERFORMANCE

For the primary comparison of the three detection systems, it is desirable to average out the effect of different operator teams and, for statistical significance, to include the maximum number of encounters. Figure III-5 shows the probability of detection versus false-alarm rate for the three systems using all encounters over all lanes visited. As noted earlier, comparison on the basis of P_d and FAR separately is difficult, especially when the spread in false-alarm rates is large, such as the difference between CRC ($0.67/m^2$) and GDE ($0.50/m^2$). Thus, the favored value for comparison is the SNR.

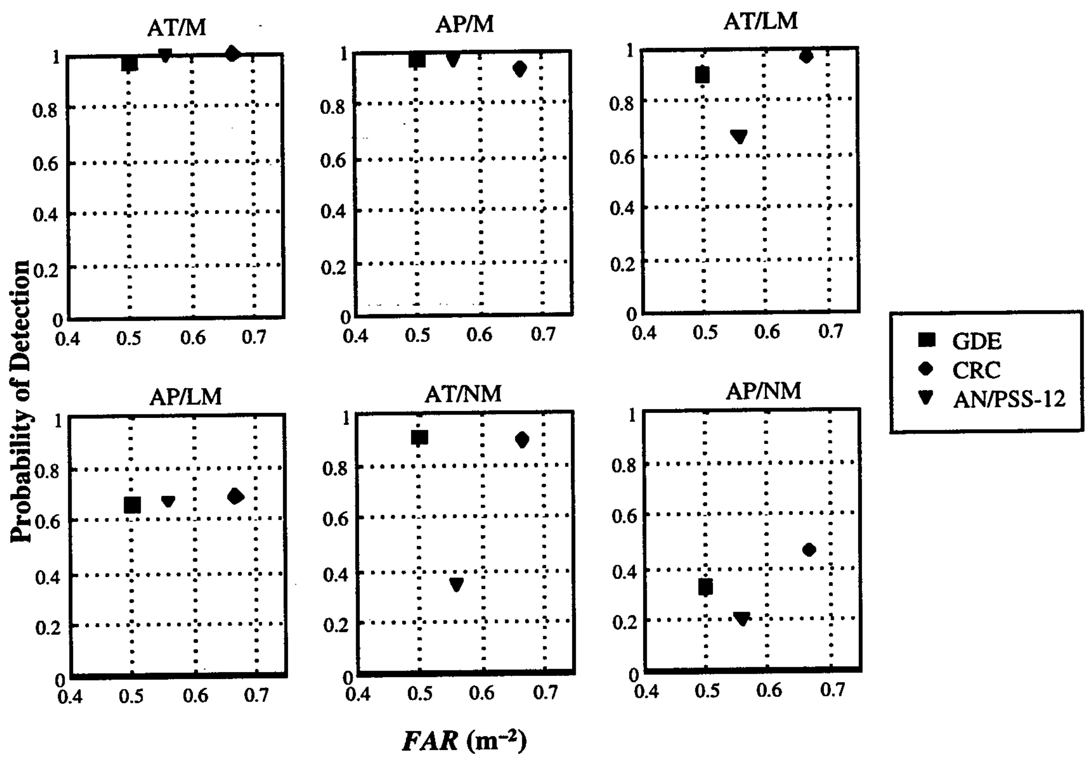


Figure III-5. December 1996 Test Results Including All Encounters by All Operators on All Lanes Visited

The main objective of the test was to determine whether either of the two contractor systems provided improved performance over the AN/PSS-12. For the AT/M, AP/M, and AP/LM mines, Table III-3 and Figure III-3 show no statistically significant difference in SNR for the three detectors. However, for the AT/LM and AT/NM, both contractor systems have significantly higher SNRs than the AN/PSS-12. For AP/NM, CRC performs better, while the performance of the GDE system is statistically the same as that of the AN/PSS-12, using the confidence intervals determined with a binomial process. Since this is an upper bound on—and potentially an overestimate of—the confidence interval, and the overlap is very slight, it is possible that the GDE system also outperforms the

AN/PSS-12. But a comparison of the confidence intervals for detection of LM and NM mines for the two contractor systems shows that there is overlap. Therefore, it can be concluded that there is no statistically significant difference between the two contractor systems.

Figure III-6 shows the P_ds of specific mine types calculated using all encounters by all operators.[7] This plot focuses on the differences in sensor ability to detect mines with different characteristics, but it should be kept in mind that the plot does not factor in the differences in false-alarm rates, so it may be misleading. Nonetheless, some interesting observations can be made. The difference between the two contractor systems and the AN/PSS-12 is largest when detecting the M19 mine. The AN/PSS-12 also shows the lowest P_d for the other AT/LM mines (except the VS2.2, where GDE and the AN/PSS-12 have the same P_d), but the discrepancy is most notable for the M19. In the case of AP/LM mines, for all three systems P_d for the VS50 is much higher than for any other mine in this category. This is because although the VS50 does not have a metal case, a metal covering on the pressure plate makes its metal content much greater than that of either the TS50 or the PMA3. This mine should probably not be classified with AP/LM mines. One can better assess the performance of the systems in finding truly low metal content AP mines if it is removed from the calculation. The P_ds for GDE, CRC, and AN/PSS-12 using only encounters with TS-50 and PMA-3 mines are 0.46, 0.49, and 0.43, respectively. They are still statistically inseparable from one another with very low probability of detection.

The attributed "detection" of NM mines by AN/PSS-12 is of particular interest, since these surrogate mines contain no metal at all. The detection probability in excess of 0.40 for the EM12 and of about 0.20 for the EM6 and EM3 implies either that the operators were using some other method, such as visual cues, to find the mines, or that the false-alarm rate was so high that a substantial fraction of the mines would be detected by luck.[8] That is, in a very high *FAR* regime, where a significant fraction of the ground is covered by alarms, high P_ds would not be surprising. Lucky matches of sensor nominations and targets contribute only about 10 percentage points to the measured P_d, implying that many AN/PSS-12 detections of NM targets were not attributed to luck.

---

7 For high metal content mines, the detection probability of the three detectors is similar and close to one. These results are not present in Figure III-6.

8 The method for calculating "lucky matches" is discussed in detail in Andrews et al. (1996). We do not present it here, because the corrections in this test are small.

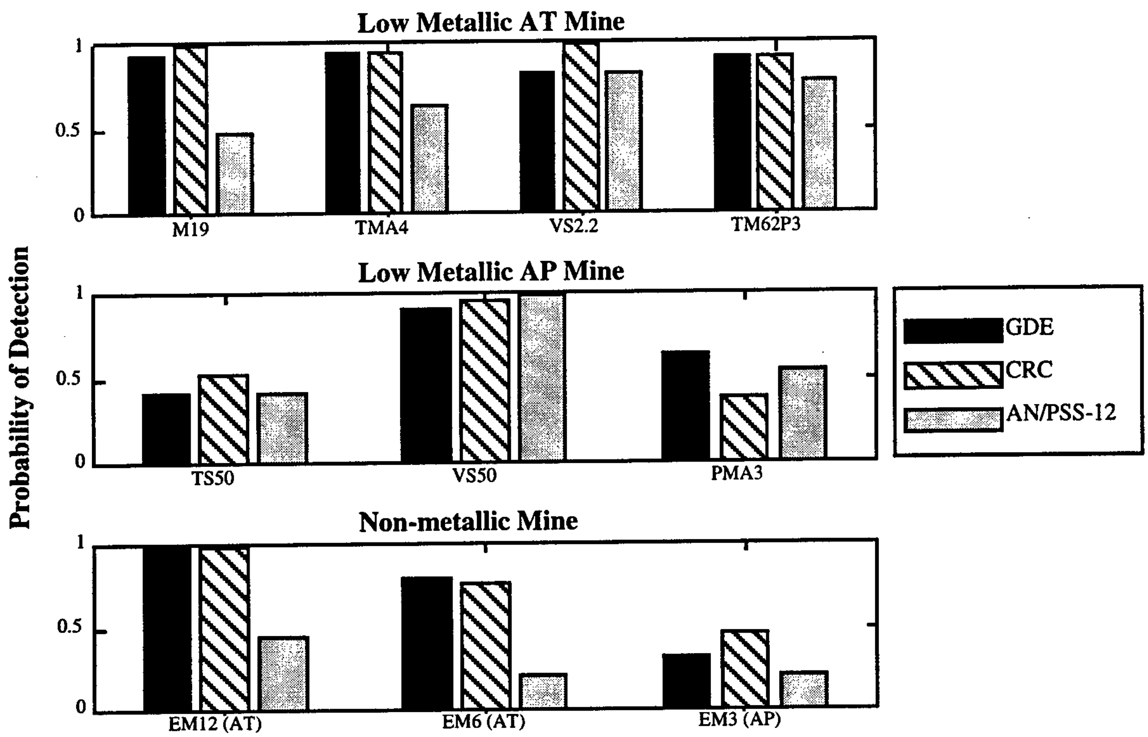


Figure III-6. Probability of Detection for Low Metallic and Nonmetallic Mines for the Three Systems Tested

D. PROBABILITY OF DETECTION vs. "*halo*" RADIUS AND LOCATION ACCURACY

Figures III-7a, III-7b, and III-7c show the detection probability as a function of the *halo* radius. Each plot provides the P_d for a single team using a single system. In Figure III-7a the detection rate for the GDE sensor is consistent across teams for each of the six different mine types. Almost all detections are achieved within 10 cm of the mine for all AT mines and AP/M. On the other hand, the detection rates for the AP/LM and AP/NM are much lower and increase gradually with the *halo* radius. This increase in P_d as a function of *halo* radius is caused by "lucky matches" (Mulqueen et al., 1995). The CRC data for AP/LM and AP/NM (Fig. III-7b) show a similar trend to that of the GDE data. Thus it can be argued that "lucky matches" also play a role for large halos. The AN/PSS-12 show a similar functional relationship between P_d and *halo* radius. The metal case mines are detected close to the edge of the mines. But the probability of detection of all LM and NM mines gradually increases as the *halo* radius increases, which is consistent with "lucky matches."

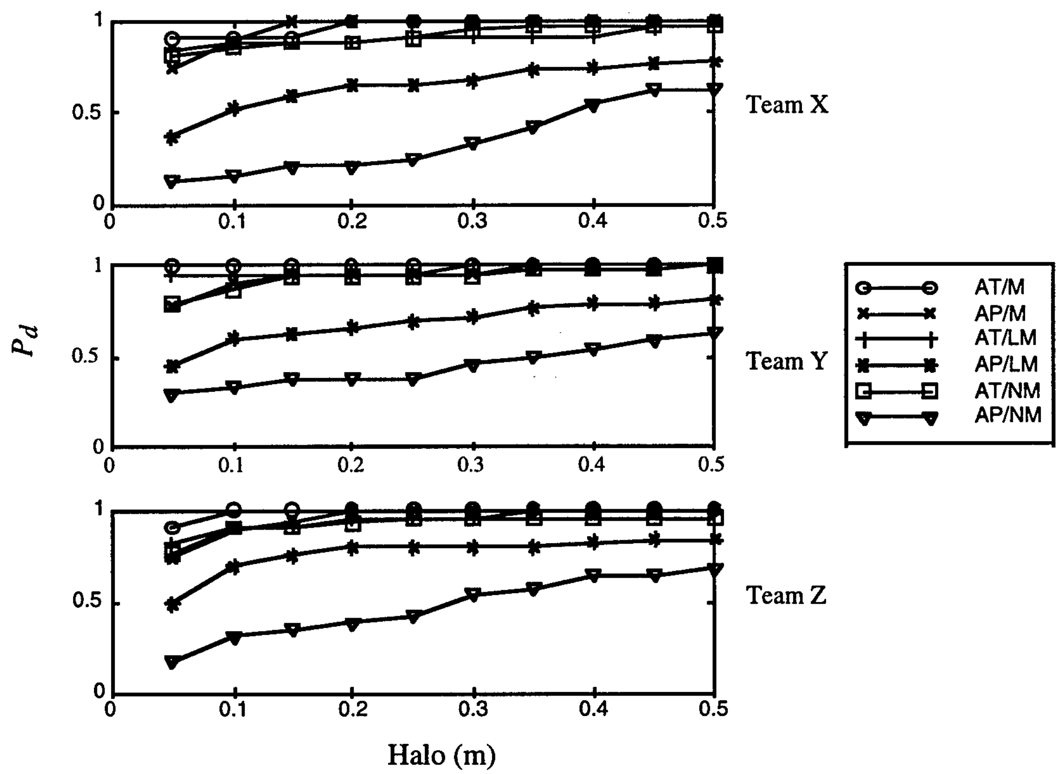


Figure III-7a. P_d vs. R_{halo} for GDE

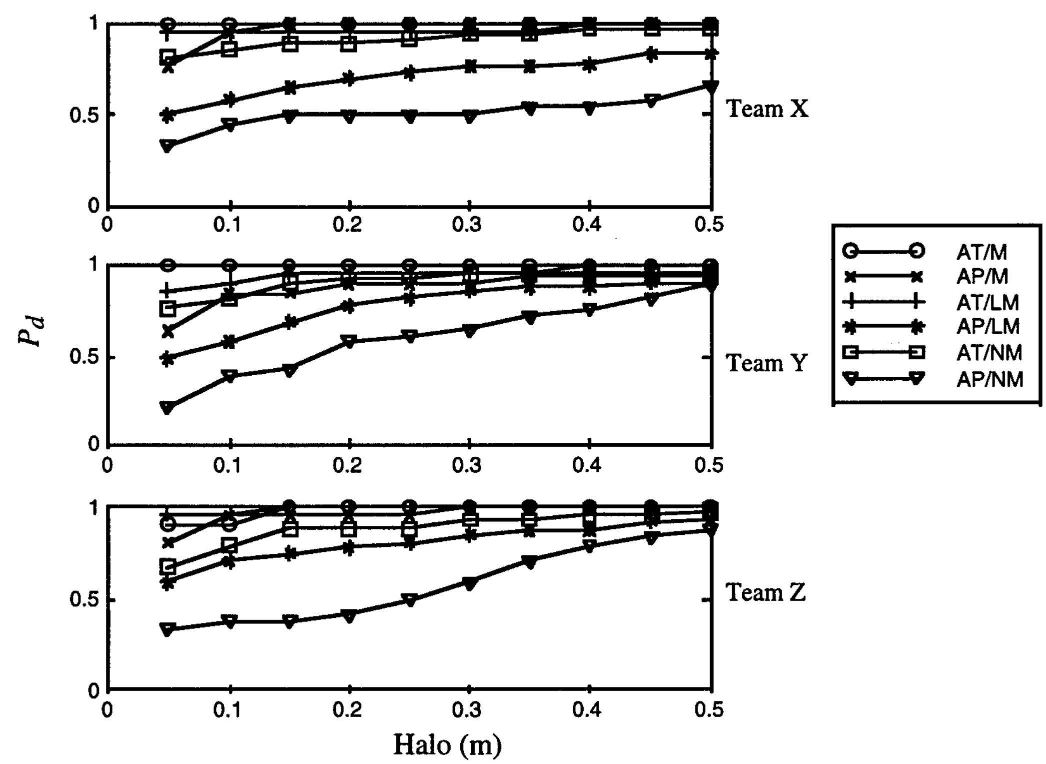


Figure III-7b. P_d vs. R_{halo} for CRC

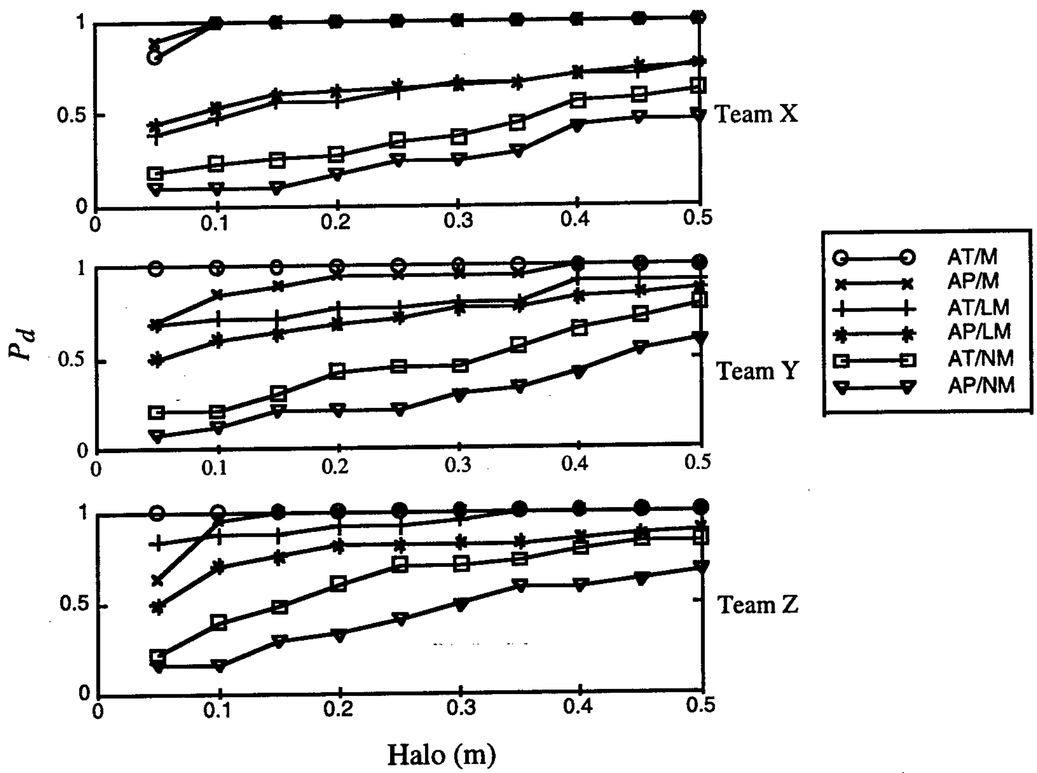


Figure III-7c. P_d vs. R_{halo} for AN/PSS-12

To assess whether the gradual increase of P_d is caused by poor location accuracy or "lucky matches," the mean mine location accuracy as measured by the distance from the declaration to the *center* of the mine, and called radial location accuracy, for each system is determined for a 15-cm *halo* radius. Here, the data indicate that all three sensors have similar capabilities. For the AN/PSS-12, the mean distance of all declarations (credited with locating a mine) is 8.5 cm (see Table III-4). The GDE and CRC systems have radial location accuracies of 8.0 cm and 8.1 cm, respectively. Table III-4 also gives the mean and standard deviation of the distance of each detection location from the edge of the mine.[9] All three systems have a mean detection location from the edge of the mine of less than 3 cm. Figure III-8a, III-8b, and III-8c show the radial distribution and distribution of the distance from the edge of the mine. For all three systems, more than half the detections are within 0.5 cm of the edge of the mine (the first bin of the histogram is 0 to 0.5 cm).

9 This is relevant because of the large difference in size between the AP and AT mines.

Table III-4. Mine Location Errors

Contractor - Team	Mean Radial Distance (cm)	Standard Deviation of Radial Distance (cm)	Mean Distance from Edge (cm)	Standard Deviation of Distance from Edge (cm)
GDE -Team X	8.2	5.0	2.2	3.7
GDE -Team Y	7.5	4.3	2.1	3.4
GDE -Team Z	8.4	5.3	2.5	3.6
Total GDE	8.0	4.9	2.3	3.5
CRC -Team X	7.7	4.7	2.1	3.6
CRC -Team Y	8.0	5.7	2.4	3.8
CRC -Team Z	8.5	6.1	2.3	3.4
Total CRC	8.1	5.5	2.3	3.4
PSS - Team X	8.4	6.2	2.8	4.0
PSS - Team Y	7.8	5.9	2.5	4.0
PSS - Team Y	9.1	6.0	3.2	4.0
Total PSS-12	8.5	6.0	2.9	4.0

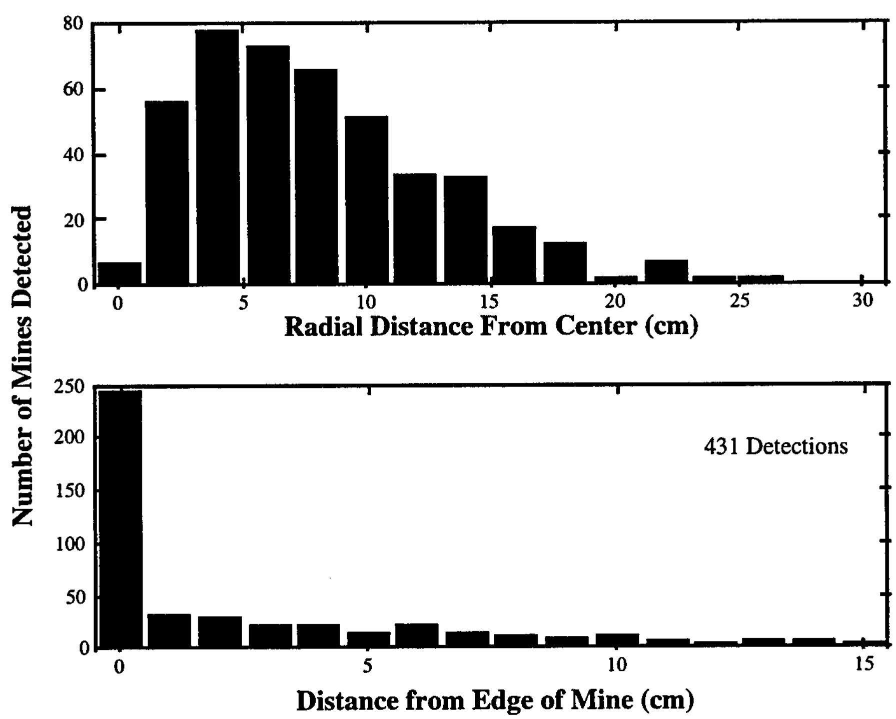


Figure III-8a. GDE Location Accuracy for All Mines Detected. There is a total of 431 detections. 244 of these are within 0.5 cm of the edge of the mine.

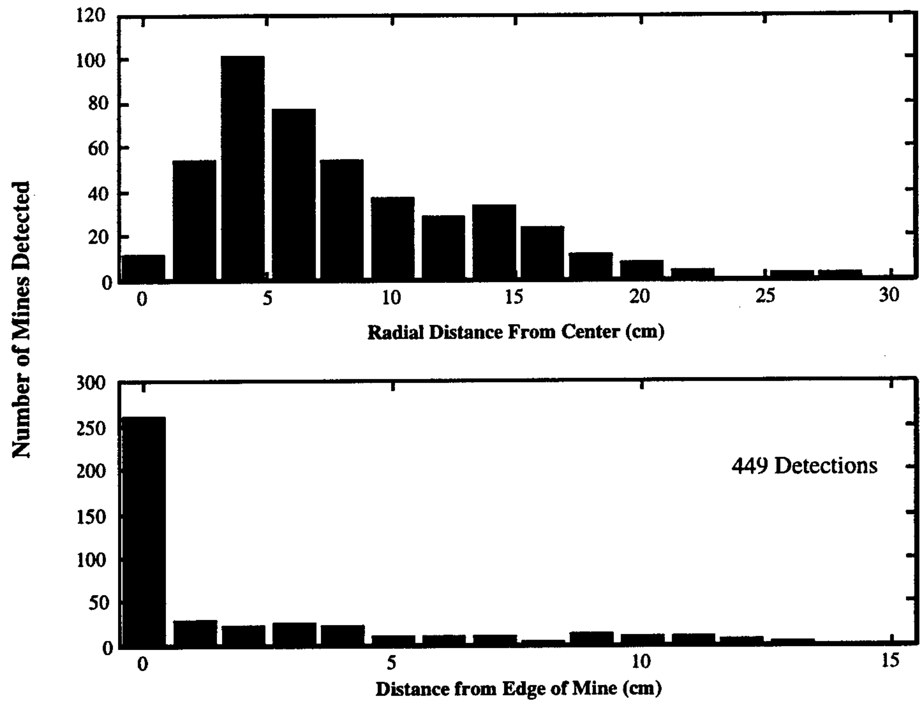


Figure III-8b. CRC Location Accuracy for All Mines Detected. There is a total of 449 detections. 261 of these are within 0.5 cm of the edge of the mine.

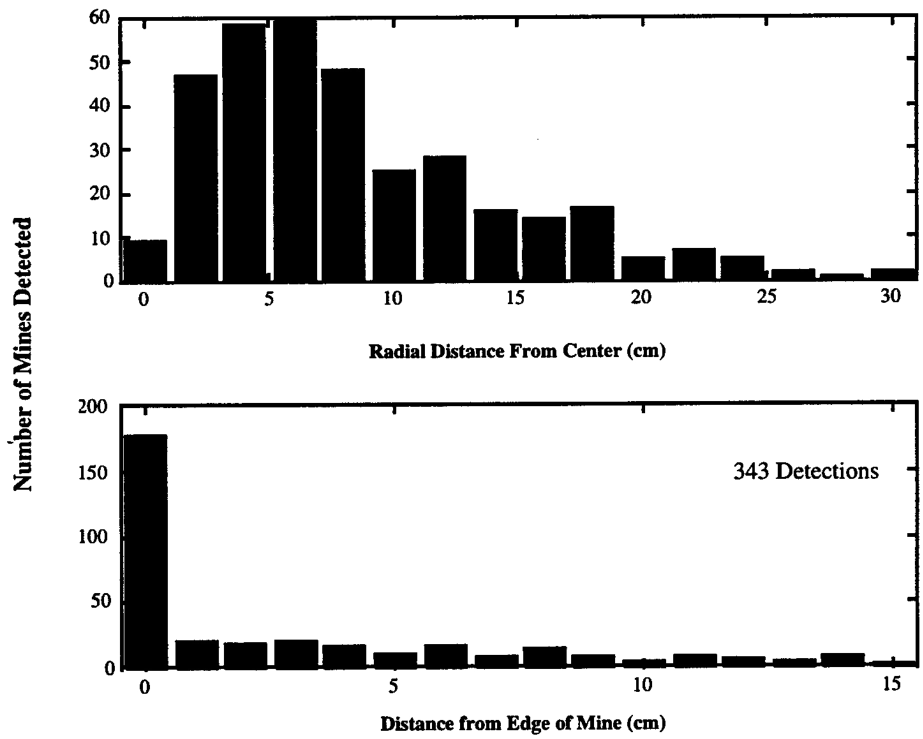


Figure III-8c. AN/PSS-12 Location Accuracy for All Mines Detected. There is a total of 343 detections. 177 of these are within 0.5 cm of the edge of the mine.

Both contractor systems use a radar, which potentially illuminates a very small region directly under the radar. Given that the GPR potentially interacts with the ground much more locally than the metal detector does, there appears to be no added location improvement. In addition, if one assumes that the GPR illumination area is small compared to that of the metal detector, then the GPR might be expected to do a better job than the metal detector at locating the mines. This does not appear to be the case.

There is also the risk that the radar subsystems did not illuminate the entire site, which might result in missed mines. If only a fraction of the mine lanes were covered by the radar, then both the detection rate and false-alarm rate are underestimated in the test results compared to what would be achieved by complete coverage. Since both systems detected approximately 40 percent of the AP/NM mines, the worst case is that the radar component of the systems only covered 40 percent of the site. If all declarations were categorized by the sensor within the system responsible for the *alarm*, it might be possible to scale the results to estimate the potential detection rate and false-alarm rate. But no breakdown of the *alarming* sensor is given. Therefore, we offer only the caveat that the potential lack of coverage of the test lanes by the integrated contractor systems may result in lower values of both P_d and *FAR*.

E. EFFECT OF OPERATORS ACROSS SYSTEMS, SYSTEMS ACROSS OPERATORS

Figures III-9, III-10, and III-11 show the performance in plots of P_d versus false-alarm rate for operator teams X, Y, and Z, respectively, using each detector system. Two types of comparisons are of interest from these plots: first, differences in performance of a single operator team using all three detector systems and second, differences in performance among all operator teams using the same detector system.

We look first at differences in detector systems. Each team reported fewer false alarms with the GDE system than with either the CRC or the AN/PSS-12. The important question is whether this decrease in *FAR* comes at an acceptable cost in P_d. For team X, the P_d was considerably lower for the GDE system in detecting AP/NM mines and was slightly lower in detecting all LM mines. For team Y, there is no significant difference in P_d for GDE and CRC systems. For team Z, P_d was lower for the GDE system in detecting AT/LM mines. For other mine types, there was no significant difference.

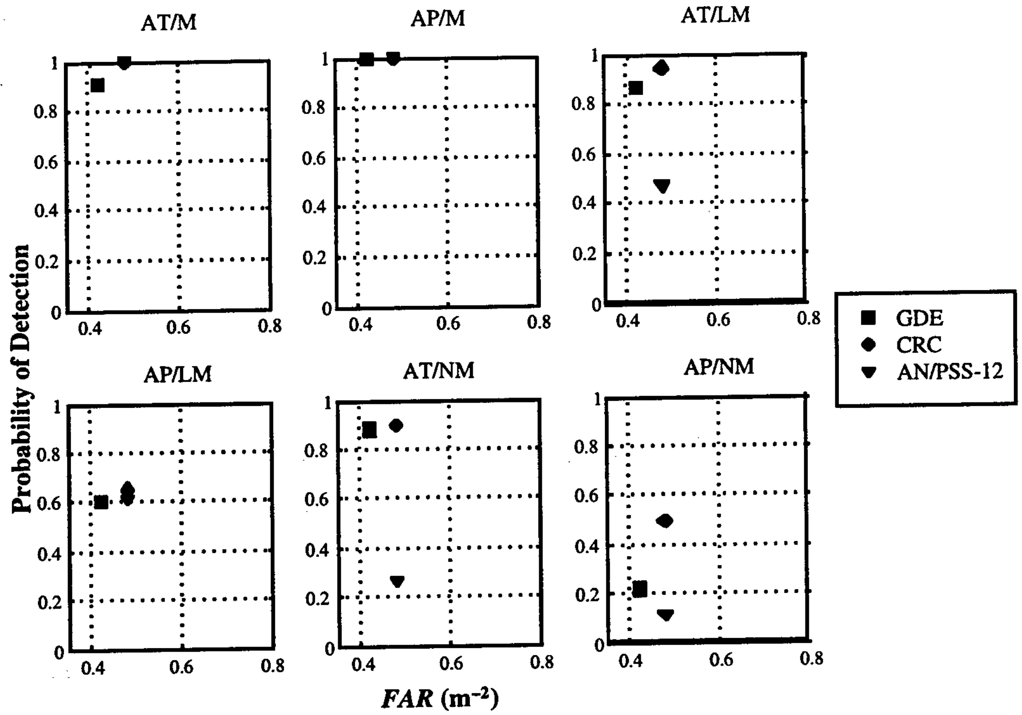


Figure III-9. P_d vs. *FAR* for Team X for All Encounters

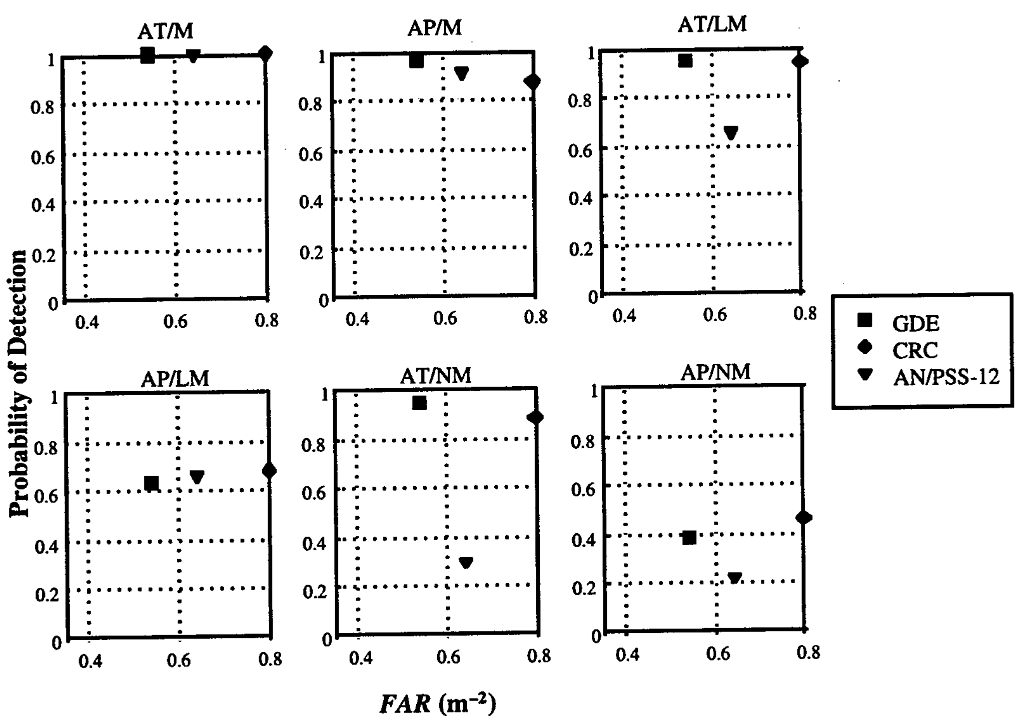


Figure III-10. P_d vs. *FAR* for Team Y for All Encounters

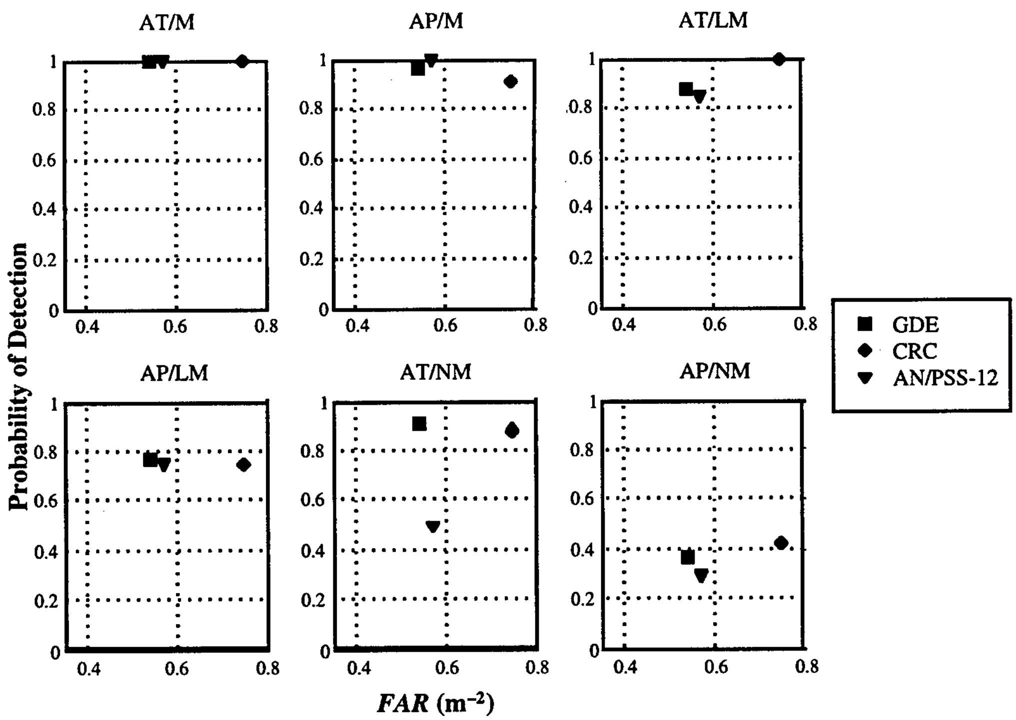


Figure III-11. P_d vs. *FAR* for Team Z for All Encounters

With only three operator teams, there is not a large enough statistical sample to average out operator differences. Therefore, the effect of the different operators using the same detection system is also of interest. Here, one observes that team X reported fewer false alarms than teams Y or Z for all three systems. Again, the effect on P_d must be assessed. When operating the GDE system, most P_ds were 5 to 10 percentage points lower for team X than for teams Y or Z. When operating the CRC system, little or no difference is observed in P_d among teams X, Y, and Z. For the AN/PSS-12, P_d for team Z was higher when detecting LM and NM mines.[10] Since these comparisons are all made on a reduced sample size, it is important to consider the statistical confidence limits on the measured P_ds.

Figures III-12, III-13, and III-14 track the *FAR* and scan rate, or rate to advance, for the operator team/detector combinations as the test progressed. From these plots, we want to determine if performance improved with time, as the operators became more familiar with the equipment. First, we note that it is difficult to deduce anything about P_d

10 The AN/PSS-12 should not detect the NM mines. The relatively high P_d for operator team Z in detection of NM mines with a metal detector suggests that this team was better able to employ some other means, such as visual cues, to aid in detection.

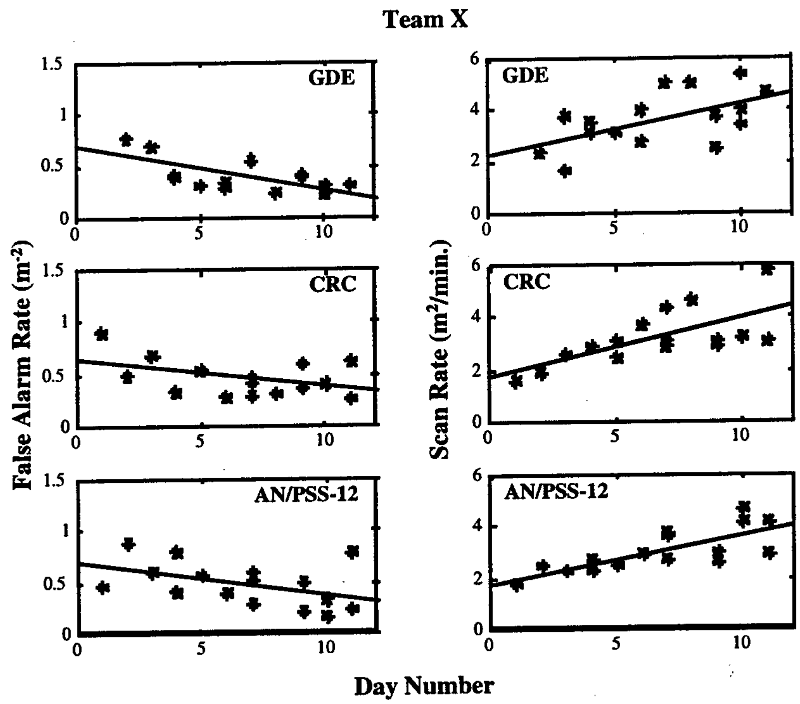


Figure III-12. False Alarm and Scan Rate vs. Test Day for Team X with All Detectors. Weekends are not included. There is a trend toward reduced *FAR* as the testing progresssed. In addition, the overall scan rate tended to increase.

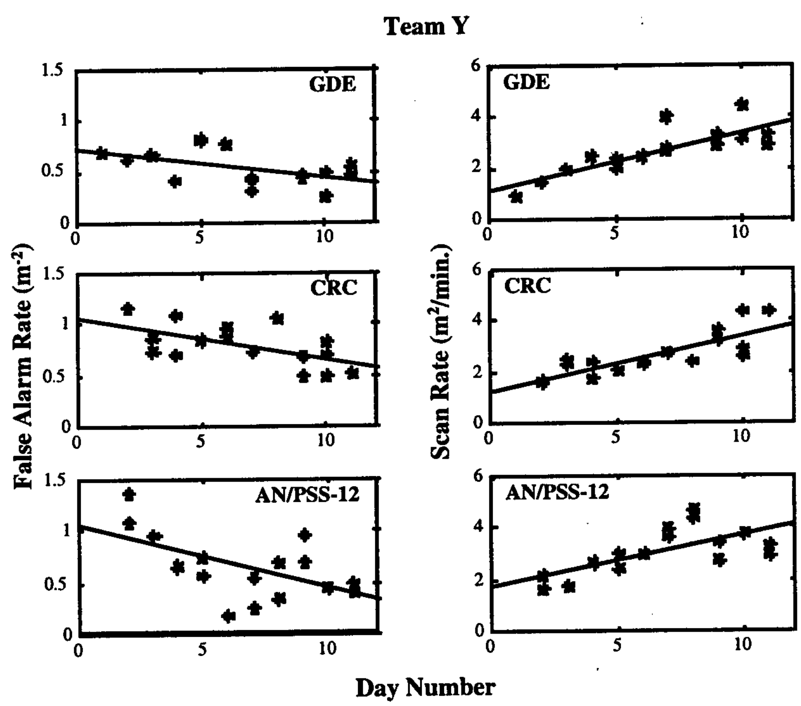


Figure III-13. False Alarm and Scan Rate vs. Test Day for Team Y with All Detectors. Weekends are not included. There is a trend toward reduced *FAR* as the testing progresssed. In addition, the overall scan rate tended to increase.

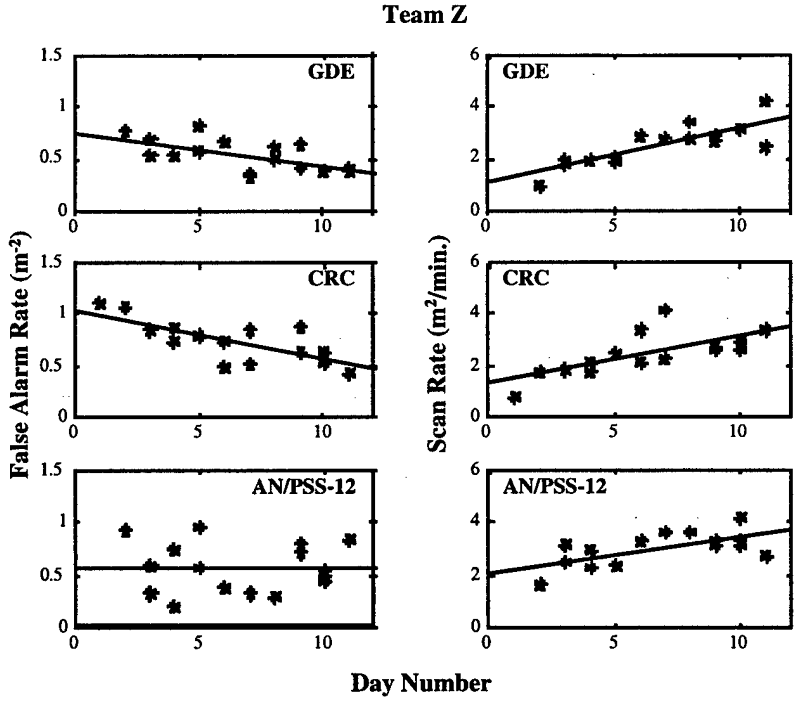


Figure III-14. False Alarm and Scan Rate vs. Test Day for Team Z with All Detectors. Weekends are not included. There is a trend toward reduced *FAR* as the testing progresssed for all systems except the AN/PSS-12. In addition, the overall scan rate tended to increase.

because the different lanes, which contain a different mix of mines,[11] were searched in different order by the operator team/detector combinations. Second, as noted earlier, the clutter density, which will be the primary driver for changes in *FAR*, should be somewhat similar among the lanes. Third, the scan rate also may depend on target population and clutter variability.

For most operator teams with most systems, the scan rate increased and the false-alarm rate decreased over the course of the test. In the only case where this was not so, team Z operating the AN/PSS-12, the *FAR* was flat throughout the test. When a linear regression analysis is performed on the data, the correlation coefficient indicates that the trends are not statistically compelling; that is, none of the linear correlation coefficients are greater than 0.82. Looking at the individual data points, the greatest change is seen in the first 1 or 2 days of testing, for most cases. This suggests that there is some familiarization process that operators benefit from over a short period. It should also be realized,

[11] Some lanes were all NM and may have been the hardest, some were all M and may have been the easiest, and others contained a mix representing intermediate difficulty.

however, that skewed data at one end of the test will tend to overemphasize trends in a linear regression analysis. No consistent trends were observed in the P_d data as the test progressed.

F. COMPARISON TO PREVIOUS TEST RESULTS

Results can vary by test. The local geology, clutter environment, and selection of target types will all influence both P_d and *FAR*. The two participating contractor systems in this test were evaluated in two recent demonstrations: The Close-In Man-Portable Mine Detector (CIMMD) Advanced Technology Demonstration (ATD) was held at a different site at APG in 1995, and the Army Bosnia Countermine task force demonstration was held at Fort A.P. Hill in 1996 (Andrews et al., 1996, and Morris, 1995). Because neither test included the standard AN/PSS-12, we compare performance of only the two contractor systems with these previous results.

A few words are needed about the mine classification in the original CIMMD ATD evaluation and the changes that were made in rescoring the results for the current comparison. Some of the mines in the CIMMD ATD were used without fuzes and/or detonators—the only metal parts in those mines—so these mines were completely nonmetallic, even though in their true in-use state they would contain some metal. In the original scoring of the test, the mines were classified as only metallic or nonmetallic, where nonmetallic included some low metal content mines that had their metal parts removed and other low metal content mines that retained some or all of their metal parts. We rescored the CIMMD test to divide the "nonmetallic" set into LM and NM. Table III-5 gives descriptions of the mines that were listed in the ATD report as nonmetallic, their reclassification for the current analysis, the nominal description of the mines, and the state as used in the CIMMD ATD.

Tables III-6 and III-7 summarize the results of the ATD test when it is scored in the same manner as the current test. Due to CRC equipment problems, only the GDE system was tested in the CIMMD ATD. The table contains entries for two false-alarm rates because the contractor was requested to operate the system in two modes. In Table III-6, the data presented in the third column, with a *FAR* of approximately $0.4/m^2$, are comparable to the operational mode employed at the current test. GDE reported a somewhat lower *FAR* in the CIMMD ATD than in the current test and substantially higher probabilities of detection, particularly with regard to AP/LM and AP/NM mines. However, the AP/LM category again includes the VS50 mines, which contain a large amount of metal

Table III-5. Mines in CIMMD ATD Previously Labeled "Nonmetallic" (Morris, 1995)

Mine	Class	Nominal Description	As Used in ATD
PM60	AT/NM	20 g of metal in fuze	simulant, containing no metal
VS2.2	AT/LM	small quantity of metal in fuze and detonator	included metal in fuze, but not detonator
VS1.6	AT/LM	small quantity of metal in fuze and detonator	included metal in fuze, but not detonator
VS50	AP/LM	pressure plate reinforced with metal; also in detonator	included pressure plate (largest metal component), but not detonator
VAL-69	AP/M	metal fragmentation	metal fragmentation—reclassify as high metal
T-72	AP/NM	small quantity of metal	no metal: did not use detonator, which is the only part in this model with metal
TM62P3	AT/NM	small quantity in fuze	no fuzes; all plastic
PMA3	AP/NM	small quantity of metal in detonator	no detonator; all plastic
M14	AP/LM	small quantity in firing pin and detonator	included firing pin (less than one gram of steel), but no detonator

Table III-6. CIMMD ATD Results for GDE

Mine Type	Number of Mines	*FAR* (m^{-2})	P_d	*FAR* (m^{-2}) (fast scan)	P_d (fast scan)
AT/M	26	0.39	1.0	0.02	1.0
AP/M	28	0.39	1.0	0.02	0.93
AT/LM	12	0.39	1.0	0.02	1.0
AP/LM	16	0.39	0.63	0.02	0.50
AT/NM	18	0.39	1.0	0.02	1.0
AP/NM	12	0.39	0.67	0.02	0.17

in the pressure plate. When these mines are removed from the calculation, P_d for AP/LM decreases from 0.63 to 0.38, comparable with results from the current test. The "fast scan" mode represents a request by the government that the contractor operate as quickly as possible, only looking for large (AT) mines. Comparison to the results at the higher *FAR* gives an idea of the cost in *FAR* for a modest improvement in P_d.

Table III-7. CIMMD ATD Probability of Detection for GDE by Mine Type

Type	Mine Type	Number of Mines	P_d
AT/M	TM62M	12	1.0
AT/M	TM46	14	1.0
AP/M	VAL-69	14	1.0
AP/M	M16	14	1.0
AT/LM	VS2.2	6	1.0
AT/LM	VS1.6	6	1.0
AP/LM	VS50	8	0.875
AP/LM	M14	8	0.375
AT/NM	TM62P3	8	1.0
AT/NM	PM60	10	1.0
AP/NM	T72	8	0.625
AP/NM	PMA3	4	0.75
	Total	112	0.911

Both the GDE and CRC systems were used in the APH test (Andrews et al., 1996). As shown in Table III-8, the *FAR* for both systems was much higher than in the current test. At APH, both systems had P_ds about 10 percentage points higher for AP/NM mines, and CRC had a substantially higher P_d for AP/LM mines. It should be noted with regard to the APH test that the number of encounters was very small—in the case of the AT/NM mines, only one. As a result, the statistical significance of P_d for individual mine types is poor, and differences may be the result of simple statistical fluctuations.

Table III-8. March 1996 Fort A.P. Hill Results for GDE and CRC

Mine Type	Number of Mines	GDE		CRC	
		FAR (m^{-2})	P_d	*FAR* (m^{-2})	P_d
AT/M	4	0.74	1.0	0.83	1.0
AP/M	4	0.74	1.0	0.83	1.0
AT/LM	4	0.74	1.0	0.83	0.75
AP/LM	15	0.74	0.67	0.83	0.87
AT/NM	1	0.74	1.0	0.83	1.0
AP/NM	7	0.74	0.43	0.83	0.57

We do not attempt to explain changes in results from one test to another, except to note that the current test was the first one run with soldier operators as opposed to contractor operators, so some decrease in performance would not be surprising. However, absent details of geology, weather, local clutter and the like, and without modeling the sensor response to targets in these varying environments, it is not possible to isolate their contributions to performance.

IV. CONCLUSIONS

Based on our analysis, we present the following conclusions from the December 1996 Bosnia Hand-Held Mine Detection Demonstration at Aberdeen Proving Ground:

- Both the GDE and CRC systems provide increased capability over the AN/PSS-12. This is particularly true with regard to the detection of AT/LM, AT/NM and potentially for AP/NM mines. However, both contractor systems perform poorly when attempting to detect AP/LM mines and very poorly when attempting to detect AP/NM mines. Depending on the mission, P_d for AP/LM and AP/NM, as well as *FAR* for all mine types could be problematic (Andrews et al., 1996).
- Detection of NM mines by the AN/PSS-12 indicates that visual cues may have influenced the test results. While it is true that soldiers are trained to use all their senses in the detection of mines—and these detections are legitimate from that viewpoint—such cues could obscure one-to-one comparisons of sensor performance.
- Probabilities of detection in the current test are somewhat lower than those achieved by the same systems in previous tests. This may be attributable to operation of the equipment by soldiers rather than contractor personnel, but such an effect cannot be isolated in the presence of differing clutter environments, target populations, and natural geology, among other things.

V. REFERENCES

Altshuler, Thomas W., Anne M. Andrews, and David A. Sparrow, "Mine and UXO Detection Measures of Performance and Their Implication in Real-World Scenarios," *Proc. of SPIE Detection and Remediation Technology for Mines and Mine-like Targets II*, Vol. 3079, p. 281, 1997.

Altshuler, Thomas W., et al., "Demonstrator Performance at the Unexploded Ordnance Advanced Technology Demonstration at Jefferson Proving Ground (Phase I), and Implications for UXO Clearance," IDA Paper P-3114, October 1995.

Andrews, Anne M., Vivian George, Thomas W. Altshuler, and Michael Mulqueen, "Results of the Countermine Task Force Mine Detection Technology Demonstrations at Fort A.P. Hill, Virginia, March 18–22, 1996," Institute for Defense Analyses, IDA Paper P-3192, July 1996.

Bevington, Philip R., "Data Reduction and Error Analysis for the Physical Sciences," McGraw-Hill Book Co., New York, 1969.

Blake, Lamont V., "Radar Range-Performance Analysis," Artech House, Inc., Norwood, Massachusetts, 1986.

Minkler G., and Minkler, G., "CFAR," Magellan Book Co., Baltimore, MD, 1990.

Morris, Todd A., "Abbreviated Report for the Advanced Technology Demonstration of the Close-In Manportable Mine Detector," TECOM Report No. ATC-7743, July 1995.

Morris, Todd A., "Final Report for the Technical Feasibility Test (TFT) of the Bosnia Handheld Mine Detector System (BOSHMIDS)," TECOM Report No. ATC-7933, January 1997.

Mulqueen, Michael, Vivian George, Anne Andrews, David Sparrow, Regina Dugan, "Performance Assessment at the Jefferson Proving Ground Demonstration of Systems for the Detection and Identification of Buried Unexploded Ordnance," *Proc. of SPIE Detection and Remediation Technology for Mines and Mine-like Targets*, Vol. 2496, p. 649, 1997.

Rice, S.O., "Mathematical Analogies of Random Noise, *Bell System Technical Journal*, **24**, No. 1, p. 46–56, January 1945.

Van Trees, Harry L., "Detection, Estimation and Modulation Theory," Part 1, John Wiley & Son, New York, 1968.

ACRONYMS AND ABBREVIATIONS

AN/PSS-12	Mine detector currently used by U.S. Army
AP	Antipersonnel
APG	Aberdeen Proving Ground
APH	Fort A.P. Hill
AT	Antitank
ATD	Advanced Technology Demonstration
BOSHMIDS	Bosnia Handheld Mine-Detection System
CIMMD	Close-In Man-Portable Mine Detector
CRC	Coleman Research Corporation
DIGS	Drop-In GPR Sensor
FAR	False-Alarm Rate
GDE	GDE Systems, Inc.
GPR	Ground-Penetrating Radar
IDAMTMA	Institute for Defense Analyses Target Matching Algorithm
LM	Low Metal
M	Metal
NM	No metal
P_d	Probability of Detection
P_{fa}	Probability of False Alarm
ROC	Receiver Operator Characteristic
SNR	Signal-to-Noise Ratio
TECOM	Test and Evaluation Command
TFT	Technical Feasibility Test

APPENDIX A

TEST RESULTS

APPENDIX A
TEST RESULTS

Tables A-1 through A-18 summarize the test results lane by lane. A check indicates the mine was detected by the detector and operator team combination indicated in the column heading. The mine types are described in Table I-1. The P_d reported for each lane will be strongly dependent on the mix of mines types emplaced in that lane. "Alarms" are all sensor target nominations, "detections" are mines for which the sensor indicates an alarm within the 15-cm (6-inch) halo, and "false alarms" are all alarms not within 15 cm (6 inches) of an emplaced mine. False alarms plus detections may not add to total number of alarms because multiple alarms within a halo are counted as redundant. P_d is the number of detections divided by number of mines emplaced in lane. FA/m^2 is the number of false alarms per square meter.

Tables A-19 through A-27 summarize the test results of each operator team with each system, as applicable.

Table A-1. Lane 1 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Z	GDE/Y	GDE/X	CRC/Y	CRC/X	CRC/Z	PSS-12/X	PSS-12/Z	PSS-12/Y
100	TS50	AP	LM		✓							
101	M19	AT	LM		✓	✓	✓	✓	✓			
102	TS50	AP	LM		✓		✓				✓	
103	VS2.2	AT	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alarms				53	66	33	69	43	68	68	74	72
Detections				1	4	2	3	2	2	1	2	1
False Alarms				52	62	31	65	41	66	67	72	71
P_d				0.25	1	0.50	0.75	0.50	0.50	0.25	0.50	0.25
FA/m^2				0.69	0.83	0.41	0.87	0.55	0.88	0.89	0.96	0.95

Legend:
AP = Antipersonnel
AT = Antitank
LM = Low metal

Table A-2. Lane 2 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Z	GDE/Y	GDE/X	CRC/Y	CRC/X	CRC/Z	PSS-12/X	PSS-12/Z	PSS-12/Y
200	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
201	PMA3	AP	LM	✓		✓						
202	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
203	VS2.2	AT	LM			✓	✓	✓	✓	✓	✓	✓
204	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
205	TS50	AP	LM				✓			✓	✓	✓
206	EM3	AP	NM	✓			✓	✓				
207	M19	AT	LM	✓	✓	✓	✓	✓	✓		✓	
208	M21	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
209	TS50	AP	LM						✓		✓	
210	PMA3	AP	LM	✓		✓					✓	✓
211	TS50	AP	LM	✓	✓	✓		✓	✓		✓	
212	TS50	AP	LM	✓	✓	✓			✓			
213	VS50	AP	LM	✓		✓	✓	✓	✓	✓	✓	✓
214	VAL-69	AP	M	✓		✓		✓		✓	✓	
215	EM3	AP	NM		✓		✓	✓				
216	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
217	PMA3	AP	LM	✓	✓				✓	✓	✓	
218	PMA3	AP	LM	✓	✓				✓	✓	✓	
219	VS2.2	AT	LM	✓	✓	✓	✓	✓	✓		✓	
220	M12A1	AT	M	✓	✓		✓	✓	✓	✓	✓	✓
Alarms				57	71	38	68	35	55	58	60	62
Detections				17	13	14	13	14	15	12	17	10
False Alarms				40	58	24	55	21	40	46	43	52
P_d				0.81	0.62	0.67	0.62	0.67	0.71	0.57	0.81	0.48
FA/m^2				0.53	0.77	0.32	0.73	0.28	0.53	0.61	0.57	0.69

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-3. Lane 3 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Y	GDE/X	GDE/Z	CRC/X	CRC/Z	CRC/Y	PSS-12/Z	PSS-12/Y	PSS-12/X
300	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	
301	EM3	AP	NM	✓	✓	✓		✓				
302	VS50	AP	LM	✓	✓	✓			✓	✓	✓	✓
303	TS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	
304	TS50	AP	LM		✓	✓	✓	✓		✓	✓	✓
305	TS50	AP	LM				✓	✓		✓	✓	
306	TS50	AP	LM	✓	✓	✓	✓	✓		✓	✓	✓
307	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
308	VS50	AP	LM		✓		✓	✓				
309	TMA4	AP	LM	✓	✓	✓		✓	✓		✓	✓
310	EM3	AP	NM				✓		✓			
311	EM3	AP	NM	✓	✓		✓	✓	✓			
312	PROM1	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alarms				61	43	55	77	76	59	78	51	43
Detections				9	11	9	10	11	8	8	9	6
False Alarms				52	32	46	67	65	51	69	42	37
P_d				0.69	0.85	0.69	0.77	0.85	0.62	0.62	0.69	0.46
FA/m^2				0.69	0.43	0.61	0.89	0.87	0.68	0.92	0.56	0.49

Legend:
- AP = Antipersonnel
- LM = Low metal
- M = Metal
- NM = No metal

Table A-4. Lane 4 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team					
				GDE/Z	GDE/Y	CRC/Y	CRC/X	PSS-12/X	PSS-12/Z
400	EM3	AP	NM		✓		✓		✓
401	EM12	AT	NM	✓	✓	✓	✓		✓
402	EM3	AP	NM				✓		
403	EM12	AT	NM	✓	✓	✓	✓	✓	✓
Alarms				40	45	82	53	45	65
Detections				2	3	2	4	1	3
False Alarms				38	42	80	49	44	62
P_d				0.50	0.75	0.50	1.0	0.25	0.75
FA/m^2				0.51	0.56	1.07	0.65	0.59	0.83

Legend:
- AP = Antipersonnel
- AT = Antitank
- NM = No metal

Table A-5. Lane 5 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Y	GDE/X	GDE/Z	CRC/Z	CRC/Y	CRC/X	PSS-12/Y	PSS-12/X	PSS-12/Z
No mines												
Alarms				52	50	36	64	73	45	72	29	40
Detections				0	0	0	0	0	0	0	0	0
False Alarms				52	50	36	64	73	45	72	29	40
P_d				NA	NA	NA	NA	NA	NA	NA	NA	NA
FA/m^2				0.69	0.67	0.48	0.85	0.97	0.60	0.96	0.39	0.53

Table A-6. Lane 6 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team					
				GDE/Y	GDE/X	CRC/X	CRC/Z	PSS-12/Z	PSS-12/Y
600	PMA3	AP	LM	✓					✓
601	PMA3	AP	LM	✓	✓	✓	✓	✓	
602	TS50	AP	LM						
603	TS50	AP	LM		✓	✓			
604	TMA4	AT	LM	✓	✓	✓	✓	✓	✓
605	M19	AT	LM	✓	✓	✓	✓	✓	✓
606	TS50	AP	LM	✓					
607	TS50	AP	LM	✓			✓		
608	TMA4	AT	LM	✓	✓	✓	✓	✓	
609	VS50	AP	LM	✓	✓	✓	✓	✓	✓
610	VS50	AP	LM	✓	✓	✓	✓	✓	✓
611	VS50	AP	LM	✓	✓	✓	✓	✓	✓
612	TS50	AP	LM	✓	✓	✓	✓		
613	PMA3	AP	LM	✓	✓	✓	✓	✓	✓
614	PMA3	AP	LM	✓	✓	✓			
615	M19	AT	LM	✓	✓	✓	✓	✓	✓
616	VS50	AP	LM	✓	✓	✓	✓	✓	✓
617	VS50	AP	LM	✓	✓	✓	✓	✓	✓
618	TMA4	AT	LM	✓		✓	✓	✓	✓
Alarms				48	31	38	60	36	47
Detections				17	14	15	14	12	11
False Alarms				31	17	23	46	24	36
P_d				0.89	0.74	0.79	0.74	0.63	0.58
FA/m^2				0.41	0.23	0.31	0.61	0.32	0.48

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

Table A-7. Lane 7 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team					
				GDE/Y	GDE/X	CRC/X	CRC/Z	PSS-12/Z	PSS-12/Y
700	EM6	AT	NM	✓	✓	✓	✓		✓
701	EM12	AT	NM	✓		✓	✓	✓	✓
702	VS2.2	AT	LM	✓		✓	✓		✓
703	PMA3	AP	LM				✓		✓
704	PROM1	AP	M	✓	✓	✓	✓	✓	✓
705	PROM1	AP	M	✓	✓	✓	✓	✓	✓
706	EM12	AT	NM	✓	✓	✓	✓		
707	PMA3	AP	LM			✓		✓	✓
708	VS2.2	AT	LM	✓	✓	✓	✓	✓	✓
709	PROM1	AP	NM	✓	✓	✓	✓	✓	✓
Alarms				32	30	41	55	27	40
Detections				8	6	9	9	6	9
False Alarms				24	24	32	46	21	30
P_d				0.80	0.60	0.90	0.90	0.60	0.90
FA/m^2				0.32	0.32	0.43	0.61	0.28	0.40

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-8. Lane 8 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team					
				GDE/Z	GDE/Y	CRC/Y	CRC/X	PSS-12/X	PSS-12/Z
800	EM3	AP	NM	✓					
801	EM6	AT	NM	✓	✓	✓	✓		
802	TS50	AP	LM		✓	✓			✓
803	VS50	AP	LM	✓	✓	✓	✓	✓	✓
804	VAL-69	AP	M	✓	✓	✓	✓	✓	✓
805	PROM1	AP	M	✓	✓	✓	✓	✓	✓
806	PROM1	AP	M	✓	✓	✓	✓	✓	✓
807	VAL-69	AP	M	✓	✓	✓	✓	✓	✓
808	EM6	AT	NM		✓	✓	✓		
809	EM3	AP	NM						
810	VS50	AP	LM	✓	✓	✓	✓	✓	✓
811	VS50	AP	LM	✓		✓	✓	✓	✓
812	TS50	AP	LM	✓			✓		
813	M19	AT	LM	✓	✓	✓	✓		✓
Alarms				36	45	66	31	28	46
Detections				11	10	11	11	7	9
False Alarms				25	35	55	20	21	37
P_d				0.79	0.71	0.79	0.79	0.50	0.64
FA/m^2				0.33	0.47	0.73	0.27	0.28	0.49

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-9. Lane 9 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Y	GDE/X	GDE/Z	CRC/X	CRC/Z	CRC/Y	PSS-12/Z	PSS-12/Y	PSS-12/X
900	VAL-69	AP	M	✓	✓	✓	✓	✓		✓		✓
901	PROM1	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
902	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
903	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
904	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
905	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
906	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
907	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
908	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
909	PROM1	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
910	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alarms				42	33	40	36	48	47	25	28	23
Detections				11	11	11	11	11	10	11	10	11
False Alarms				31	22	29	25	37	37	14	18	12
P_d				1.0	1.0	1.0	1.0	1.0	0.91	1.0	0.91	1.0
FA/m^2				0.41	0.29	0.39	0.33	0.49	0.49	0.19	0.24	0.16

Legend:

AP = Antipersonnel

AT = Antitank

M = Metal

Table A-10. Lane 10 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team					
				GDE/X	GDE/Z	CRC/Z	CRC/Y	PSS-12/Y	PSS-12/X
1000	EM12	AT	NM	✓	✓	✓	✓		✓
1001	EM6	AT	NM	✓	✓	✓	✓		
1002	EM6	AT	NM		✓		✓		
1003	EM3	AP	NM						
1004	EM3	AP	NM			✓			
1005	EM12	AT	NM	✓	✓	✓	✓		
1006	EM12	AT	NM	✓	✓	✓	✓		
1007	EM3	AP	NM	✓	✓	✓			
1008	EM12	AT	NM	✓	✓	✓	✓		✓
1009	EM12	AT	NM	✓	✓	✓	✓		✓
1010	EM6	AT	NM	✓	✓	✓			✓
1011	EM3	AP	NM	✓	✓	✓	✓		
1012	EM12	AT	NM	✓	✓	✓	✓		
Alarms				28	40	50	47	25	21
Detections				10	11	11	9	0	4
False Alarms				18	29	39	38	25	17
P_d				0.77	0.85	0.85	0.69	0	0.31
FA/m²				0.24	0.39	0.52	0.51	0.33	0.23

Legend:

AP = Antipersonnel

AT = Antitank

NM = No metal

Table A-11. Lane 11 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Y	GDE/X	GDE/Z	CRC/X	CRC/Z	CRC/Y	PSS-12/Z	PSS-12/Y	PSS-12/X
1100	VS2.2	AT	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1101	PROM1	AP	M	✓	✓	✓	✓	✓		✓	✓	✓
1102	EM6	AT	NM	✓	✓	✓	✓	✓				
1103	M21	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alarms				54	30	52	56	60	55	47	16	27
Detections				4	4	4	4	4	2	3	3	3
False Alarms				50	26	48	52	56	53	44	13	24
P_d				1.0	1.0	1.0	1.0	1.0	0.5	0.75	0.75	0.75
FA/m²				0.67	0.35	0.64	0.69	0.75	0.71	0.59	0.17	0.32

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-12. Lane 12 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Y	GDE/X	GDE/Z	CRC/X	CRC/Z	CRC/Y	PSS-12/Z	PSS-12/Y	PSS-12/X
1200	M19	AT	LM	✓	✓	✓	✓	✓	✓	✓		
1201	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		
1202	VAL-69	AP	M	✓	✓		✓	✓	✓	✓	✓	✓
1203	TS50	AP	LM			✓	✓	✓	✓		✓	✓
1204	TS50	AP	LM									
1205	TS50	AP	LM	✓	✓				✓		✓	
1206	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1207	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1208	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1209	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1210	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1211	VS50	AP	LM	✓		✓	✓	✓	✓	✓	✓	✓
1212	TS50	AP	LM				✓	✓		✓		✓
1213	TS50	AP	LM	✓				✓	✓	✓	✓	
1214	TS50	AP	LM			✓				✓	✓	
Alarms				58	32	41	48	71	49	26	67	25
Detections				11	9	10	11	12	12	12	11	9
False Alarms				47	23	31	37	59	37	24	56	16
P_d				0.73	0.60	0.67	0.73	0.80	0.80	0.80	0.73	0.60
FA/m²				0.63	0.31	0.41	0.49	0.79	0.49	0.32	0.75	0.21

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-13. Lane 13 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/X	GDE/Z	GDE/Y	CRC/Z	CRC/Y	CRC/X	PSS-12/Y	PSS-12/X	PSS-12/Z
1300	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		✓
1301	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1302	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1303	VS50	AP	LM	✓	✓			✓	✓	✓	✓	✓
1304	VS50	AP	LM	✓	✓		✓	✓	✓	✓	✓	✓
1305	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		✓
1306	TM62P3	AT	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1307	TS50	AP	LM	✓			✓	✓		✓		✓
1308	TS50	AP	LM	✓			✓	✓		✓	✓	✓
1309	EM3	AP	NM				✓					
1310	EM3	AP	NM		✓	✓		✓	✓			
1311	EM3	AP	NM			✓		✓				
1312	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1313	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1314	EM3	AP	NM						✓			
1315	EM3	AP	NM				✓			✓	✓	✓
1316	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1317	TS50	AP	LM		✓			✓	✓			✓
1318	TS50	AP	LM	✓	✓							
1319	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓	✓	
Alarms				44	42	30	69	82	44	63	49	47
Detections				14	14	11	14	16	14	14	11	14
False Alarms				30	28	19	55	66	30	49	38	33
P_d				0.70	0.70	0.55	0.70	0.80	0.70	0.70	0.55	0.70
FA/m^2				0.40	0.37	0.25	0.73	0.88	0.40	0.65	0.51	0.44

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-14. Lane 14 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Z	GDE/Y	GDE/X	CRC/Y	CRC/X	CRC/Z	PSS-12/X	PSS-12/Z	PSS-12/Y
1400	EM3	AP	NM									
1401	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		
1402	EM6	AT	NM	✓	✓	✓	✓	✓	✓		✓	
1403	TS50	AP	LM	✓								
1404	TS50	AP	LM				✓		✓	✓	✓	✓
1405	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1406	EM6	AT	NM	✓	✓	✓	✓	✓	✓		✓	
1407	EM3	AP	NM	✓			✓	✓	✓			
1408	TS50	AP	LM	✓				✓	✓		✓	
1409	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1410	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1411	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓	✓	
1412	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1413	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1414	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alarms				70	70	40	99	54	60	44	66	58
Detections				13	10	10	12	12	13	9	11	7
False Alarms				57	60	30	87	41	47	35	55	51
P_d				0.87	0.67	0.67	0.80	0.80	0.87	0.60	0.73	0.47
FA/m^2				0.76	0.80	0.40	1.16	0.55	0.63	0.47	0.73	0.68

Legend:
- AP = Antipersonnel
- AT = Antitank
- LM = Low metal
- M = Metal
- NM = No metal

Table A-15. Lane 15 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team					
				GDE/X	GDE/Z	CRC/Z	CRC/Y	PSS-12/Y	PSS-12/X
1500	TS50	AP	LM		✓	✓	✓	✓	✓
1501	VS50	AP	LM		✓	✓	✓	✓	✓
1502	TM62P3	AT	LM	✓	✓	✓		✓	
1503	VS50	AP	LM	✓	✓	✓	✓	✓	✓
1504	TS50	AP	LM		✓	✓	✓		
1505	TS50	AP	LM	✓		✓	✓	✓	✓
1506	TS50	AP	LM		✓	✓			
1507	VS50	AP	LM	✓	✓	✓	✓	✓	✓
1508	TMA4	AT	LM	✓	✓	✓	✓		✓
1509	TS50	AP	LM		✓		✓		
1510	VS50	AP	LM	✓	✓	✓	✓	✓	✓
1511	TM62P3	AT	LM	✓	✓	✓	✓		
1512	TS50	AP	LM		✓	✓			
1513	TMA4	AT	LM	✓	✓	✓	✓		
Alarms				50	46	77	73	48	65
Detections				8	13	13	11	7	7
False Alarms				42	32	64	62	41	58
P_d				0.57	0.93	0.93	0.78	0.50	0.50
FA/m^2				0.56	0.43	0.85	0.83	0.55	0.77

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

Table A-16. Lane 16 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/X	GDE/Z	GDE/Y	CRC/Z	CRC/Y	CRC/X	PSS-12/Y	PSS-12/X	PSS-12/Z
1600	EM6	AT	NM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1601	EM12	AT	NM	✓	✓	✓	✓	✓	✓			
1602	EM3	AP	NM		✓				✓	✓		✓
1603	EM6	AT	NM	✓					✓			
1604	EM3	AP	NM									
1605	EM12	AT	NM	✓	✓	✓		✓	✓			
1606	EM3	AP	NM			✓		✓				
1607	EM6	AT	NM				✓	✓				
1608	EM3	AP	NM	✓		✓		✓	✓	✓	✓	✓
1609	EM6	AT	NM	✓	✓	✓	✓	✓	✓	✓		
1610	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		
1611	EM12	AT	NM	✓	✓	✓	✓	✓	✓			✓
1612	EM12	AT	NM	✓	✓	✓	✓	✓	✓			✓
1613	EM3	AP	NM									✓
1614	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		
1615	EM6	AT	NM	✓	✓	✓	✓		✓			✓
1616	EM12	AT	NM	✓	✓	✓	✓	✓	✓			✓
1617	EM6	AT	NM			✓		✓				
1618	EM12	AT	NM	✓	✓	✓	✓	✓	✓	✓		✓
1619	EM6	AT	NM		✓	✓		✓	✓			
1620	EM12	AT	NM	✓	✓	✓	✓		✓			
Alarms				72	57	51	95	97	44	109	61	69
Detections				14	14	16	12	15	16	7	2	9
False Alarms				58	43	35	83	82	28	102	59	60
P_d				0.67	0.67	0.76	0.57	0.71	0.76	0.33	0.10	0.43
FA/m^2				0.77	0.57	0.47	1.11	1.09	0.37	1.36	0.79	0.80

Legend:

AP = Antipersonnel

AT = Antitank

NM = No metal

Table A-17. Lane 17 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/Z	GDE/Y	GDE/X	CRC/Y	CRC/X	CRC/Z	PSS-12/X	PSS-12/Z	PSS-12/Y
1700	EM6	AT	NM	✓	✓	✓	✓		✓			
1701	EM3	AP	NM				✓				✓	✓
1702	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1703	VS50	AP	LM	✓	✓		✓	✓	✓	✓	✓	✓
1704	VS50	AP	LM		✓		✓	✓	✓	✓	✓	✓
1705	TM62P3	AT	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1706	EM6	AT	NM	✓	✓	✓	✓		✓		✓	
1707	EM6	AT	NM	✓	✓	✓	✓	✓	✓			
1708	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1709	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1710	M12A1	AT	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1711	TMA4	AT	LM	✓	✓	✓	✓	✓	✓		✓	✓
1712	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
1713	VAL-69	AP	M	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alarms				53	46	30	68	46	61	40	41	44
Detections				12	13	11	14	11	13	9	12	11
False Alarms				41	33	19	53	35	48	31	28	33
P_d				0.86	0.93	0.79	1.0	0.79	0.93	0.64	0.86	0.79
FA/m^2				0.55	0.44	0.25	0.71	0.47	0.64	0.41	0.37	0.44

Legend:

AP = Antipersonnel
AT = Antitank
LM = Low metal
M = Metal
NM = No metal

Table A-18. Lane 18 Results

Mine ID	Type	Size	Metal	System Designator/Operator Team								
				GDE/X	GDE/Z	GDE/Y	CRC/Z	CRC/Y	CRC/X	PSS-12/Y	PSS-12/X	PSS-12/Z
1800	EM3	AP	NM		✓	✓	✓	✓	✓	✓	✓	✓
1801	VS50	AP	LM	✓	✓	✓	✓	✓	✓	✓	✓	✓
1802	TM62P3	AT	LM		✓	✓	✓	✓	✓	✓	✓	✓
1803	EM3	AP	NM		✓		✓	✓				
1804	VAL-69	AP	M	✓	✓	✓		✓	✓	✓	✓	✓
Alarms				54	66	37	85	68	28	85	46	57
Detections				2	5	4	4	5	4	4	4	4
False Alarms				52	661	33	81	63	24	81	42	53
P_d				0.40	1.0	0.80	0.80	1.0	0.80	0.80	0.80	0.80
FA/m^2				0.69	0.81	0.44	1.08	0.84	0.32	1.08	0.56	0.71

Legend:

AP = Antipersonnel

AT = Antitank

LM = Low metal

M = Metal

NM = No metal

Table A-19. Summary of Operator X with GDE

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	*	0/0	0/0	0/0	*	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**2/2**
M12A1	0/0	0/1	0/0	*	0/0	0/0	0/0	*	3/3	0/0	0/0	1/1	1/1	1/1	0/0	0/0	2/2	0/0	**8/9**
Subtotal	*0/0*	*1/2*	*0/0*	*	*0/0*	*0/0*	*0/0*	*	*3/3*	*0/0*	*1/1*	*1/1*	*1/1*	*1/1*	*0/0*	*0/0*	*2/2*	*0/0*	***10/11***
AP/M																			
VAL-69	0/0	3/3	0/0	*	0/0	0/0	0/0	*	6/6	0/0	0/0	1/1	0/0	2/2	0/0	0/0	2/2	1/1	**15/15**
PROM1	0/0	0/0	1/1	*	0/0	0/0	3/3	*	2/2	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**7/7**
Subtotal	*0/0*	*3/3*	*1/1*	*	*0/0*	*0/0*	*3/3*	*	*8/8*	*0/0*	*1/1*	*1/1*	*0/0*	*2/2*	*0/0*	*0/0*	*2/2*	*1/1*	***22/22***
AT/LM																			
M19	1/1	1/1	0/0	*	0/0	2/2	0/0	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	**5/5**
TMA4	0/0	0/0	1/1	*	0/0	2/3	0/0	*	0/0	0/0	0/0	0/0	0/0	0/0	2/2	0/0	1/1	0/0	**6/7**
VS2.2	1/1	2/2	0/0	*	0/0	0/0	1/2	*	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**5/6**
TM62P3	0/0	0/0	0/0	*	0/0	0/0	0/0	*	0/0	0/0	0/0	0/0	1/1	0/0	2/2	0/0	1/1	0/1	**4/5**
Subtotal	*2/2*	*3/3*	*1/1*	*	*0/0*	*4/5*	*1/2*	*	*0/0*	*0/0*	*1/1*	*1/1*	*1/1*	*0/0*	*4/4*	*0/0*	*2/2*	*0/1*	***20/23***
AP/LM																			
TS50	0/2	2/4	3/4	*	0/0	2/5	0/0	*	0/0	0/0	0/0	1/6	3/4	0/3	1/6	0/0	0/0	0/0	**12/34**
VS50	0/0	3/3	4/4	*	0/0	5/5	0/0	*	0/0	0/0	0/0	3/4	5/5	3/3	3/4	0/0	2/4	1/1	**29/33**
PMA3	0/0	2/4	0/0	*	0/0	3/4	0/2	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**5/10**
Subtotal	*0/2*	*7/11*	*7/8*	*	*0.0*	*10/14*	*0/2*	*	*0/0*	*0/0*	*0/0*	*4/10*	*8/9*	*3/6*	*4/10*	*0/0*	*2/4*	*1/7*	***46/77***
AT/NM																			
EM12	0/0	0/0	0/0	*	0/0	0/0	2/2	*	0/0	6/6	0/0	2/2	4/4	2/2	0/0	9/9	0/0	0/0	**25/25**
EM6	0/0	0/0	0/0	*	0/0	0/0	0/1	*	0/0	2/3	1/1	0/0	0/0	2/2	0/0	4/7	3/3	0/0	**12/17**
Subtotal	*0/0*	*0/0*	*0/0*	*	*0/0*	*0/0*	*2/3*	*	*0/0*	*8/9*	*1/1*	*2/2*	*4/4*	*4/4*	*0/0*	*13/16*	*3/3*	*0/0*	***37/42***
AP/NM																			
EM3	0/0	0/2	2/3	*	0/0	0/0	0/0	*	0/0	2/4	0/0	0/0	0/5	0/2	0/0	1/5	0/1	0/2	**5/24**
Subtotal	*0/0*	*0/2*	*2/3*	*	*0/0*	*0/0*	*0/0*	*	*0/0*	*2/4*	*0/0*	*0/0*	*0/5*	*0/2*	*0/0*	*1/5*	*0/1*	*0/2*	***5/24***
Total	**2/4**	**14/21**	**11/13**	*	**0/0**	**14/19**	**6/10**	*	**11/11**	**10/13**	**4/4**	**9/15**	**14/20**	**10/15**	**8/14**	**14/21**	**11/14**	**2/5**	**140/199**

Legend:

AP/M = Antipersonnel
AT/M = Antitank/metal
AP/LM = Antipersonnel/low metal
AT/LM = Antitank/low metal
AP/NM = Antipersonnel/no metal
AP/NM = Antitank/no metal

* = Not searched.

Table A-20. Summary of Operator Y with GDE

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	2/2
M12A1	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	3/3	*	0/0	1/1	1/1	1/1	*	0/0	2/2	0/0	9/9
Subtotal	*0/0*	*2/2*	*0/0*	*0/0*	*0/0*	*0/0*	*0/0*	*0/0*	*3/3*	*	*1/1*	*1/1*	*1/1*	*1/1*	*	*0/0*	*2/2*	*0/0*	*11/11*
AP/M																			
VAL-69	0/0	2/3	0/0	0/0	0/0	0/0	0/0	2/2	6/6	*	0/0	1/1	0/0	2/2	*	0/0	2/2	1/1	16/17
PROM1	0/0	0/0	1/1	0/0	0/0	0/0	3/3	2/2	2/2	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	9/9
Subtotal	*0/0*	*2/3*	*1/1*	*0/0*	*0/0*	*0/0*	*3/3*	*4/4*	*8/8*	*	*1/1*	*1/1*	*0/0*	*2/2*	*	*0/0*	*2/2*	*1/1*	*25/26*
AT/LM																			
M19	1/1	1/1	0/0	0/0	0/0	2/2	0/0	1/1	0/0	*	0/0	1/1	0/0	0/0	*	0/0	0/0	0/0	6/6
TMA4	0/0	0/0	1/1	0/0	0/0	3/3	0/0	0/0	0/0	*	0/0	0/0	0/0	0/0	*	0/0	1/1	0/0	5/5
VS2.2	1/1	1/2	0/0	0/0	0/0	0/0	2/2	0/0	0/0	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	5/6
TM62P3	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	*	0/0	0/0	1/1	0/0	*	0/0	1/1	1/1	3/3
Subtotal	*2/2*	*2/3*	*1/1*	*0/0*	*0/0*	*5/5*	*2/2*	*1/1*	*0/0*	*	*1/1*	*1/1*	*1/1*	*0/0*	*	*0/0*	*2/2*	*1/1*	*19/20*
AP/LM																			
TS50	2/2	2/4	1/4	0/0	0/0	3/5	0/0	1/2	0/0	*	0/0	2/6	0/4	0/3	*	0/0	0/0	0/0	11/30
VS50	0/0	2/3	4/4	0/0	0/0	5/5	0/0	2/3	0/0	*	0/0	4/4	3/5	3/3	*	0/0	4/4	1/1	28/32
PMA3	0/0	2/4	0/0	0/0	0/0	4/4	0/2	0/0	0/0	*	0/0	0/0	0/0	0/0	*	0/0	0/0	0/0	6/10
Subtotal	*2/2*	*6/11*	*5/8*	*0/0*	*0/0*	*12/14*	*0/2*	*3/5*	*0/0*	*	*0/0*	*6/10*	*3/9*	*3/6*	*	*0/0*	*4/4*	*1/1*	*45/72*
AT/NM																			
EM12	0/0	0/0	0/0	2/2	0/0	0/0	2/2	0/0	0/0	*	0/0	2/2	4/4	2/2	*	9/9	0/0	0/0	21/21
EM6	0/0	0/0	0/0	0/0	0/0	0/0	1/1	2/2	0/0	*	1/1	0/0	0/0	2/2	*	5/7	3/3	0/0	14/16
Subtotal	*0/0*	*0/0*	*0/0*	*2/2*	*0/0*	*0/0*	*3/3*	*2/2*	*0/0*	*	*1/1*	*2/2*	*4/4*	*4/4*	*	*14/16*	*3/3*	*0/0*	*35/37*
AP/NM																			
EM3	0/0	1/2	2/3	1/2	0/0	0/0	0/0	0/2	0/0	*	0/0	0/0	2/5	0/2	*	2/5	0/1	1/2	9/24
Subtotal	*0/0*	*1/2*	*2/3*	*1/2*	*0/0*	*0/0*	*0/0*	*0/2*	*0/0*	*	*0/0*	*0/0*	*2/5*	*0/2*	*	*2/5*	*0/1*	*1/2*	*9/24*
Total	**4/4**	**13/21**	**9/13**	**3/4**	**0/0**	**17/19**	**8/10**	**10/14**	**11/11**	*	**4/4**	**11/15**	**11/20**	**10/15**	*	**16/21**	**13/14**	**4/5**	**144/190**

Legend:

AP/M = Antipersonnel
AT/M = Antitank/metal
AP/LM = Antipersonnel/low metal
AT/LM = Antitank/low metal
AP/NM = Antipersonnel/no metal
AP/NM = Antitank/no metal

* = Not searched.

Table A-21. Summary of Operator Z with GDE

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	0/0	0/0	*	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**2/2**
M12A1	0/0	1/1	0/0	0/0	0/0	*	*	0/0	3/3	0/0	0/0	1/1	1/1	1/1	0/0	0/0	2/2	0/0	**9/9**
Subtotal	*0/0*	*2/2*	*0/0*	*0/0*	*0/0*	*	*	*0/0*	*3/3*	*0/0*	*1/1*	*1/1*	*1/1*	*1/1*	*0/0*	*0/0*	*2/2*	*0/0*	***11/11***
AP/M																			
VAL-69	0/0	3/3	0/0	0/0	0/0	*	*	2/2	6/6	0/0	0/0	0/1	0/0	2/2	0/0	0/0	2/2	1/1	**16/17**
PROM1	0/0	0/0	1/1	0/0	0/0	*	*	2/2	2/2	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**6/6**
Subtotal	*0/0*	*3/3*	*1/1*	*0/0*	*0/0*	*	*	*4/4*	*8/8*	*0/0*	*1/1*	*0/1*	*0/0*	*2/2*	*0/0*	*0/0*	*2/2*	*1/1*	***22/23***
AT/LM																			
M19	0/1	1/1	0/0	0/0	0/0	*	*	1/1	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	**3/4**
TMA4	0/0	0/0	1/1	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/2	0/0	1/1	0/0	**4/4**
VS2.2	1/1	1/2	0/0	0/0	0/0	*	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**3/4**
TM62P3	0/0	0/0	0/0	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	1/1	0/0	2/2	0/0	1/1	1/1	**5/5**
Subtotal	*1/2*	*2/3*	*1/1*	*0/0*	*0/0*	*	*	*1/1*	*0/0*	*0/0*	*1/1*	*1/1*	*1/1*	*0/0*	*4/4*	*0/0*	*2/2*	*1/1*	***15/17***
AP/LM																			
TS50	0/2	2/4	2/4	0/0	0/0	*	*	1/2	0/0	0/0	0/0	2/6	2/4	2/3	5/6	0/0	0/0	0/0	**16/31**
VS50	0/0	3/3	4/4	0/0	0/0	*	*	3/3	0/0	0/0	0/0	4/4	5/5	3/3	4/4	0/0	3/4	1/1	**30/31**
PMA3	0/0	4/4	0/0	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**4/4**
Subtotal	*0/2*	*9/11*	*6/8*	*0/0*	*0/0*	*	*	*4/5*	*0/0*	*0/0*	*0/0*	*6/10*	*7/9*	*5/6*	*9/10*	*0/0*	*3/4*	*1/1*	***50/66***
AT/NM																			
EM12	0/0	0/0	0/0	2/2	0/0	*	*	0/0	0/0	6/6	0/0	2/2	4/4	2/2	0/0	9/9	0/0	0/0	**25/25**
EM6	0/0	0/0	0/0	0/0	0/0	*	*	1/2	0/0	3/3	1/1	0/0	0/0	2/2	0/0	4/7	3/3	0/0	**14/18**
Subtotal	*0/0*	*0/0*	*0/0*	*2/2*	*0/0*	*	*	*1/2*	*0/0*	*9/9*	*1/1*	*2/2*	*4/4*	*4/4*	*0/0*	*13/16*	*3/3*	*0/0*	***39/43***
AP/NM																			
EM3	0/0	1/2	1/3	0/2	0/0	*	*	1/2	0/0	2/4	0/0	0/0	1/5	1/2	0/0	1/5	0/1	2/2	**10/28**
Subtotal	*0/0*	*1/2*	*1/3*	*0/2*	*0/0*	*	*	*1/2*	*0/0*	*2/4*	*0/0*	*0/0*	*1/5*	*1/2*	*0/0*	*1/5*	*0/1*	*2/2*	***10/28***
Total	**1/4**	**17/21**	**9/13**	**2/4**	**0/0**	*	*	**11/14**	**11/11**	**11/13**	**4/4**	**10/15**	**14/20**	**13/15**	**13/14**	**14/21**	**12/14**	**5/5**	**147/188**

Legend:

AP/M = Antipersonnel — AT/M = Antitank/metal

AP/LM = Antipersonnel/low metal — AT/LM = Antitank/low metal

AP/NM = Antipersonnel/no metal — AP/NM = Antitank/no metal

* = Not searched.

Table A-22. Summary of Operator X with CRC

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	2/2
M12A1	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	3/3	*	0/0	1/1	1/1	1/1	*	0/0	2/2	0/0	9/9
Subtotal	*0/0*	*2/2*	*0/0*	*0/0*	*0/0*	*0/0*	*0/0*	*0/0*	*3/3*	*	*1/1*	*1/1*	*1/1*	*1/1*	*	*0/0*	*2/2*	*0/0*	*11/11*
AP/M																			
VAL-69	0/0	3/3	0/0	0/0	0/0	0/0	0/0	2/2	6/6	*	0/0	1/1	0/0	2/2	*	0/0	2/2	1/1	17/17
PROM1	0/0	0/0	1/1	0/0	0/0	0/0	3/3	2/2	2/2	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	9/9
Subtotal	*0/0*	*3/3*	*1/1*	*0/0*	*0/0*	*0/0*	*3/3*	*4/4*	*8/8*	*	*1/1*	*1/1*	*0/0*	*2/2*	*	*0/0*	*2/2*	*1/1*	*26/26*
AT/LM																			
M19	1/1	1/1	0/0	0/0	0/0	2/2	0/0	1/1	0/0	*	0/0	1/1	0/0	0/0	*	0/0	0/0	0/0	6/6
TMA4	0/0	0/0	0/1	0/0	0/0	3/3	0/0	0/0	0/0	*	0/0	0/0	0/0	0/0	*	0/0	1/1	0/0	4/5
VS2.2	1/1	2/2	0/0	0/0	0/0	0/0	2/2	0/0	0/0	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	6/6
TM62P3	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	*	0/0	0/0	1/1	0/0	*	0/0	1/1	1/1	3/3
Subtotal	*2/2*	*3/3*	*0/1*	*0/0*	*0/0*	*5/5*	*2/2*	*1/1*	*0/0*	*	*1/1*	*1/1*	*1/1*	*0/0*	*	*0/0*	*2/2*	*1/1*	*19/20*
AP/LM																			
TS50	0/2	1/4	4/4	0/0	0/0	2/5	0/0	1/2	0/0	*	0/0	2/6	1/4	1/3	*	0/0	0/0	0/0	12/30
VS50	0/0	3/3	3/4	0/0	0/0	5/5	0/0	3/3	0/0	*	0/0	4/4	5/5	3/3	*	0/0	4/4	1/1	31/32
PMA3	0/0	0/4	0/0	0/0	0/0	3/4	1/2	0/0	0/0	*	0/0	0/0	0/0	0/0	*	0/0	0/0	0/0	4/10
Subtotal	*0/2*	*4/11*	*7/8*	*0/0*	*0/0*	*10/14*	*1/2*	*4/5*	*0/0*	*	*0/0*	*6/10*	*6/9*	*4/6*	*	*0/0*	*4/4*	*1/1*	*47/72*
AT/NM																			
EM12	0/0	0/0	0/0	2/2	0/0	0/0	2/2	0/0	0/0	*	0/0	2/2	4/4	2/2	*	9/9	0/0	0/0	21/21
EM6	0/0	0/0	0/0	0/0	0/0	0/0	1/1	2/2	0/0	*	1/1	0/0	0/0	2/2	*	5/7	1/3	0/0	12/16
Subtotal	*0/0*	*0/0*	*0/0*	*2/2*	*0/0*	*0/0*	*3/3*	*2/2*	*0/0*	*	*1/1*	*2/2*	*4/4*	*4/4*	*	*14/16*	*1/3*	*0/0*	*33/37*
AP/NM																			
EM3	0/0	2/2	2/3	2/2	0/0	0/0	0/0	0/2	0/0	*	0/0	0/0	2/5	1/2	*	2/5	0/1	1/2	12/24
Subtotal	*0/0*	*2/2*	*2/3*	*2/2*	*0/0*	*0/0*	*0/0*	*0/2*	*0/0*	*	*0/0*	*0/0*	*2/5*	*1/2*	*	*2/5*	*0/1*	*1/2*	*12/24*
Total	**2/4**	**14/21**	**10/13**	**4/4**	**0/0**	**15/19**	**9/10**	**11/14**	**11/11**	*	**4/4**	**11/15**	**14/20**	**12/15**	*	**16/21**	**11/14**	**4/5**	**148/190**

Legend:

AP/M = Antipersonnel

AP/LM = Antipersonnel/low metal

AP/NM = Antipersonnel/no metal

AT/M = Antitank/metal

AT/LM = Antitank/low metal

AP/NM = Antitank/no metal

* = Not searched.

Table A-23. Summary of Operator Y with CRC

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
									AT/M										
M21	0/0	1/1	0/0	0/0	0/0	*	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**2/2**
M12A1	0/0	1/1	0/0	0/0	0/0	*	*	0/0	3/3	0/0	0/0	1/1	1/1	1/1	0/0	0/0	2/2	0/0	**9/9**
Subtotal	*0/0*	*2/2*	*0/0*	*0/0*	*0/0*	*	*	*0/0*	*3/3*	*0/0*	*1/1*	*1/1*	*1/1*	*1/1*	*0/0*	*0/0*	*2/2*	*0/0*	***11/11***
									AP/M										
VAL-69	0/0	2/3	0/0	0/0	0/0	*	*	2/2	5/6	0/0	0/0	1/1	0/0	2/2	0/0	0/0	2/2	1/1	**15/17**
PROM1	0/0	0/0	1/1	0/0	0/0	*	*	2/2	2/2	0/0	0/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**5/6**
Subtotal	*0/0*	*2/3*	*1/1*	*0/0*	*0/0*	*	*	*4/4*	*7/8*	*0/0*	*0/1*	*1/1*	*0/0*	*2/2*	*0/0*	*0/0*	*2/2*	*1/1*	**20/23**
									AT/LM										
M19	1/1	1/1	0/0	0/0	0/0	*	*	1/1	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	**4/4**
TMA4	0/0	0/0	1/1	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/2	0/0	1/1	0/0	**4/4**
VS2.2	1/1	2/2	0/0	0/0	0/0	*	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**4/4**
TM62P3	0/0	0/0	0/0	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	1/1	0/0	1/2	0/0	1/1	1/1	**4/5**
Subtotal	*2/2*	*3/3*	*1/1*	*0/0*	*0/0*	*	*	*1/1*	*0/0*	*0/0*	*1/1*	*1/1*	*1/1*	*0/0*	*3/4*	*0/0*	*2/2*	*1/1*	***16/17***
									AP/LM										
TS50	1/2	1/4	1/4	0/0	0/0	*	*	1/2	0/0	0/0	0/0	3/6	3/4	1/3	5/6	0/0	0/0	0/0	**16/31**
VS50	0/0	3/3	3/4	0/0	0/0	*	*	3/3	0/0	0/0	0/0	4/4	5/5	3/3	3/4	0/0	4/4	1/1	**29/31**
PMA3	0/0	0/4	0/0	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**0/4**
Subtotal	*1/2*	*4/11*	*4/8*	*0/0*	*0/0*	*	*	*4/5*	*0/0*	*0/0*	*0/0*	*7/10*	*8/9*	*4/6*	*8/10*	*0/0*	*4/4*	*1/1*	***45/66***
									AT/NM										
EM12	0/0	0/0	0/0	2/2	0/0	*	*	0/0	0/0	6/6	0/0	2/2	4/4	2/2	0/0	8/9	0/0	0/0	**24/25**
EM6	0/0	0/0	0/0	0/0	0/0	*	*	2/2	0/0	2/3	0/1	0/0	0/0	2/2	0/0	5/7	3/3	0/0	**14/18**
Subtotal	*0/0*	*0/0*	*0/0*	*2/2*	*0/0*	*	*	*2/2*	*0/0*	*8/9*	*0/1*	*2/2*	*4/4*	*4/4*	*0/0*	*13/16*	*3/3*	*0/0*	***38/43***
									AP/NM										
EM3	0/0	2/2	2/3	0/2	0/0	*	*	0/2	0/0	1/4	0/0	0/0	2/5	1/2	0/0	2/5	1/1	2/2	**13/28**
Subtotal	*0/0*	*2/2*	*2/3*	*0/2*	*0/0*	*	*	*0/2*	*0/0*	*1/4*	*0/0*	*0/0*	*2/5*	*1/2*	*0/0*	*2/5*	*1/1*	*2/2*	***13/28***
Total	**3/4**	**13/21**	**8/13**	**3/4**	**0/0**	*	*	**11/14**	**10/11**	**9/13**	**2/4**	**12/15**	**16/20**	**12/15**	**11/14**	**15/21**	**14/14**	**5/5**	**143/188**

Legend:

AP/M = Antipersonnel — AT/M = Antitank/metal

AP/LM = Antipersonnel/low metal — AT/LM = Antitank/low metal

AP/NM = Antipersonnel/no metal — AP/NM = Antitank/no metal

* = Not searched.

Table A-24. Summary of Operator Z with CRC

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	*	0/0	0/0	0/0	*	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**2/2**
M12A1	0/0	1/1	0/0	*	0/0	0/0	0/0	*	3/3	0/0	0/0	1/1	1/1	1/1	0/0	0/0	2/2	0/0	**9/9**
Subtotal	*0/0*	*2/2*	*0/0*	*	*0/0*	*0/0*	*0/0*	*	*3/3*	*0/0*	*1/1*	*1/1*	*1/1*	*1/1*	*0/0*	*0/0*	*2/2*	*0/0*	***11/11***
AP/M																			
VAL-69	0/0	2/3	0/0	*	0/0	0/0	0/0	*	6/6	0/0	0/0	1/1	0/0	2/2	0/0	0/0	2/2	0/1	**13/15**
PROM1	0/0	0/0	1/1	*	0/0	0/0	3/3	*	2/2	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**7/7**
Subtotal	*0/0*	*2/3*	*1/1*	*	*0/0*	*0/0*	*3/3*	*	*8/8*	*0/0*	*1/1*	*1/1*	*0/0*	*2/2*	*0/0*	*0/0*	*2/2*	*0/1*	***20/22***
AT/LM																			
M19	1/1	1/1	0/0	*	0/0	2/2	0/0	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	**5/5**
TMA4	0/0	0/0	1/1	*	0/0	3/3	0/0	*	0/0	0/0	0/0	0/0	0/0	0/0	2/2	0/0	1/1	0/0	**7/7**
VS2.2	1/1	2/2	0/0	*	0/0	0/0	2/2	*	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**6/6**
TM62P3	0/0	0/0	0/0	*	0/0	0/0	0/0	*	0/0	0/0	0/0	0/0	1/1	0/0	2/2	0/0	1/1	1/1	**5/5**
Subtotal	*2/2*	*3/3*	*1/1*	*	*0/0*	*5/5*	*2/2*	*	*0/0*	*0/0*	*1/1*	*1/1*	*1/1*	*0/0*	*4/4*	*0/0*	*2/2*	*1/1*	***23/23***
AP/LM																			
TS50	0/2	3/4	4/4	*	0/0	2/5	0/0	*	0/0	0/0	0/0	3/6	2/4	2/3	5/6	0/0	0/0	0/0	**21/34**
VS50	0/0	3/3	3/4	*	0/0	5/5	0/0	*	0/0	0/0	0/0	4/4	4/5	3/3	4/4	0/0	4/4	1/1	**31/33**
PMA3	0/0	2/4	0/0	*	0/0	2/4	1/2	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	**5/10**
Subtotal	*0/2*	*8/11*	*7/8*	*	*0/0*	*9/14*	*1/2*	*	*0/0*	*0/0*	*0/0*	*7/10*	*6/9*	*5/6*	*9/10*	*0/0*	*4/4*	*1/1*	***57/77***
AT/NM																			
EM12	0/0	0/0	0/0	*	0/0	0/0	2/2	*	0/0	6/6	0/0	2/2	4/4	2/2	0/0	8/9	0/0	0/0	**24/25**
EM6	0/0	0/0	0/0	*	0/0	0/0	1/1	*	0/0	2/3	1/1	0/0	0/0	2/2	0/0	4/7	3/3	0/0	**13/17**
Subtotal	*0/0*	*0/0*	*0/0*	*	*0/0*	*0/0*	*3/3*	*	*0/0*	*8/9*	*1/1*	*2/2*	*4/4*	*4/4*	*0/0*	*12/16*	*3/3*	*0/0*	***37/42***
AP/NM																			
EM3	0/0	0/2	2/3	*	0/0	0/0	0/0	*	0/0	3/4	0/0	0/0	2/5	1/2	0/0	0/5	0/1	2/2	**10/24**
Subtotal	*0/0*	*0/2*	*2/3*	*	*0/0*	*0/0*	*0/0*	*	*0/0*	*3/4*	*0/0*	*0/0*	*2/5*	*1/2*	*0/0*	*0/5*	*0/1*	*2/2*	***10/24***
Total	**2/4**	**15/21**	**11/13**	*	**0/0**	**14/19**	**9/10**	*	**11/11**	**11/13**	**4/4**	**12/15**	**14/20**	**13/15**	**13/14**	**12/21**	**13/14**	**4/5**	**158/199**

Legend:

AP/M = Antipersonnel

AT/M = Antitank/metal

AP/LM = Antipersonnel/low metal

AT/LM = Antitank/low metal

AP/NM = Antipersonnel/no metal

AP/NM = Antitank/no metal

* = Not searched.

Table A-25. Summary of Operator X with PSS-12

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	0/0	0/0	*	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/2
M12A1	0/0	1/1	0/0	0/0	0/0	*	*	0/0	3/3	0/0	0/0	1/1	1/1	1/1	0/0	0/0	2/2	0/0	9/9
Subtotal	*0/0*	*2/2*	*0/0*	*0/0*	*0/0*	*	*	*0/0*	*3/3*	*0/0*	*1/1*	*1/1*	*1/1*	*1/1*	*0/0*	*0/0*	*2/2*	*0/0*	*11/11*
AP/M																			
VAL-69	0/0	3/3	0/0	0/0	0/0	*	*	2/2	6/6	0/0	0/0	1/1	0/0	2/2	0/0	0/0	2/2	1/1	17/17
PROM1	0/0	0/0	1/1	0/0	0/0	*	*	2/2	2/2	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	6/6
Subtotal	*0/0*	*3/3*	*1/1*	*0/0*	*0/0*	*	*	*4/4*	*8/8*	*0/0*	*1/1*	*1/1*	*0/0*	*2/2*	*0/0*	*0/0*	*2/2*	*1/1*	*23/23*
AT/LM																			
M19	0/1	0/1	0/0	0/0	0/0	*	*	0/1	0/0	0/0	0/0	0/1	0/0	0/0	0/0	0/0	0/0	0/0	0/4
TMA4	0/0	0/0	1/1	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/2	0/0	0/1	0/0	2/4
VS2.2	1/1	1/2	0/0	0/0	0/0	*	*	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	3/4
TM62P3	0/0	0/0	0/0	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	1/1	0/0	0/2	0/0	1/1	1/1	3/5
Subtotal	*1/2*	*1/3*	*1/1*	*0/0*	*0/0*	*	*	*0/1*	*0/0*	*0/0*	*1/1*	*0/1*	*1/1*	*0/0*	*1/4*	*0/0*	*1/2*	*1/1*	*8/17*
AP/LM																			
TS50	0/2	1/4	1/4	0/0	0/0	*	*	0/2	0/0	0/0	0/0	2/6	1/4	1/3	2/6	0/0	0/0	0/0	8/31
VS50	0/0	3/3	3/4	0/0	0/0	*	*	3/3	0/0	0/0	0/0	4/4	5/5	3/3	4/4	0/0	4/4	1/1	30/31
PMA3	0/0	2/4	0/0	0/0	0/0	*	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/4
Subtotal	*0/2*	*6/11*	*4/8*	*0/0*	*0/0*	*	*	*3/5*	*0/0*	*0/0*	*0/0*	*6/10*	*6/9*	*4/6*	*6/10*	*0/0*	*4/4*	*1/1*	*40/66*
AT/NM																			
EM12	0/0	0/0	0/0	1/2	0/0	*	*	0/0	0/0	3/6	0/0	1/2	2/4	2/2	0/0	0/9	0/0	0/0	9/25
EM6	0/0	0/0	0/0	0/0	0/0	*	*	0/2	0/0	1/3	0/1	0/0	0/0	0/2	0/0	1/7	0/3	0/0	2/18
Subtotal	*0/0*	*0/0*	*0/0*	*1/2*	*0/0*	*	*	*0/2*	*0/0*	*4/9*	*0/1*	*1/2*	*2/4*	*2/4*	*0/0*	*1/16*	*0/3*	*0/0*	*11/43*
AP/NM																			
EM3	0/0	0/2	0/3	0/2	0/0	*	*	0/2	0/0	0/4	0/0	0/0	1/5	0/2	0/0	1/5	0/1	1/2	3/28
Subtotal	*0/0*	*0/2*	*0/3*	*0/2*	*0/0*	*	*	*0/2*	*0/0*	*0/4*	*0/0*	*0/0*	*1/5*	*0/2*	*0/0*	*1/5*	*0/1*	*1/2*	*3/28*
Total	**1/4**	**12/21**	**6/13**	**1/4**	**0/0**	*	*	**7/14**	**11/11**	**4/13**	**3/4**	**9/15**	**11/20**	**9/15**	**7/14**	**2/21**	**9/14**	**4/5**	**96/188**

Legend:

AP/M = Antipersonnel
AP/LM = Antipersonnel/low metal
AP/NM = Antipersonnel/no metal
AT/M = Antitank/metal
AT/LM = Antitank/low metal
AP/NM = Antitank/no metal

* = Not searched.

Table A-26. Summary of Operator Y with PSS-12

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	*	0/0	0/0	0/0	*	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/2
M12A1	0/0	1/1	0/0	*	0/0	0/0	0/0	*	3/3	0/0	0/0	1/1	1/1	1/1	0/0	0/0	2/2	0/0	9/9
Subtotal	*0/0*	*2/2*	*0/0*	*	*0/0*	*0/0*	*0/0*	*	*3/3*	*0/0*	*1/1*	*1/1*	*1/1*	*1/1*	*0/0*	*0/0*	*2/2*	*0/0*	*11/11*
AP/M																			
VAL-69	0/0	2/3	0/0	*	0/0	0/0	0/0	*	5/6	0/0	0/0	1/1	0/0	2/2	0/0	0/0	2/2	1/1	13/15
PROM1	0/0	0/0	1/1	*	0/0	0/0	3/3	*	2/2	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	7/7
Subtotal	*0/0*	*2/3*	*1/1*	*	*0/0*	*0/0*	*3/3*	*	*7/8*	*0/0*	*1/1*	*1/1*	*0/0*	*2/2*	*0/0*	*0/0*	*2/2*	*1/1*	*20/22*
AT/LM																			
M19	0/1	0/1	0/0	*	0/0	2/2	0/0	*	0/0	0/0	0/0	0/1	0/0	0/0	0/0	0/0	0/0	0/0	2/5
TMA4	0/0	0/0	1/1	*	0/0	2/3	0/0	*	0/0	0/0	0/0	0/0	0/0	0/0	0/2	0/0	1/1	0/0	4/7
VS2.2	1/1	1/2	0/0	*	0/0	0/0	2/2	*	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	5/6
TM62P3	0/0	0/0	0/0	*	0/0	0/0	0/0	*	0/0	0/0	0/0	0/0	1/1	0/0	1/2	0/0	1/1	1/1	4/5
Subtotal	*1/2*	*1/3*	*1/1*	*	*0/0*	*4/5*	*2/2*	*	*0/0*	*0/0*	*1/1*	*0/1*	*1/1*	*0/0*	*1/4*	*0/0*	*2/2*	*1/1*	*15/23*
AP/LM																			
TS50	0/2	1/4	3/4	*	0/0	0/5	0/0	*	0/0	0/0	0/0	4/6	2/4	1/3	2/6	0/0	0/0	0/0	13/34
VS50	0/0	3/3	4/4	*	0/0	5/5	0/0	*	0/0	0/0	0/0	4/4	5/5	3/3	4/4	0/0	4/4	1/1	33/33
PMA3	0/0	1/4	0/0	*	0/0	2/4	2/2	*	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	5/10
Subtotal	*0/2*	*5/11*	*7/8*	*	*0/0*	*7/14*	*2/2*	*	*0/0*	*0/0*	*0/0*	*8/10*	*7/9*	*4/6*	*6/10*	*0/0*	*4/4*	*1/1*	*51/77*
AT/NM																			
EM12	0/0	0/0	0/0	*	0/0	0/0	1/2	*	0/0	0/6	0/0	1/2	4/4	0/2	0/0	3/9	0/0	0/0	9/25
EM6	0/0	0/0	0/0	*	0/0	0/0	1/1	*	0/0	0/3	0/1	0/0	0/0	0/2	0/0	2/7	0/3	0/0	3/17
Subtotal	*0/0*	*0/0*	*0/0*	*	*0/0*	*0/0*	*2/3*	*	*0/0*	*0/9*	*0/1*	*1/2*	*4/4*	*0/4*	*0/0*	*5/16*	*0/3*	*0/0*	*12/42*
AP/NM																			
EM3	0/0	0/2	0/3	*	0/0	0/0	0/0	*	0/0	0/4	0/0	0/0	1/5	0/2	0/0	2/5	1/1	1/2	5/24
Subtotal	*0/0*	*0/2*	*0/3*	*	*0/0*	*0/0*	*0/0*	*	*0/0*	*0/4*	*0/0*	*0/0*	*1/5*	*0/2*	*0/0*	*2/5*	*1/1*	*1/2*	*5/24*
Total	**1/4**	**10/21**	**9/13**	*	**0/0**	**11/19**	**9/10**	*	**10/11**	**0/13**	**3/4**	**11/15**	**14/20**	**7/15**	**7/14**	**7/21**	**11/14**	**4/5**	**114/199**

Legend:

AP/M = Antipersonnel
AP/LM = Antipersonnel/low metal
AP/NM = Antipersonnel/no metal

AT/M = Antitank/metal
AT/LM = Antitank/low metal
AP/NM = Antitank/no metal

* = Not searched.

Table A-27. Summary of Operator Z with PSS-12

Mine Type	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11	Lane 12	Lane 13	Lane 14	Lane 15	Lane 16	Lane 17	Lane 18	Total
AT/M																			
M21	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	2/2
M12A1	0/0	1/1	0/0	0/0	0/0	0/0	0/0	0/0	3/3	*	0/0	1/1	1/1	1/1	*	0/0	2/2	0/0	9/9
Subtotal	*0/0*	*2/2*	*0/0*	*0/0*	*0/0*	*0/0*	*0/0*	*0/0*	*3/3*	*	*1/1*	*1/1*	*1/1*	*1/1*	*	*0/0*	*2/2*	*0/0*	*11/11*
AP/M																			
VAL-69	0/0	3/3	0/0	0/0	0/0	0/0	0/0	2/2	6/6	*	0/0	1/1	0/0	2/2	*	0/0	2/2	1/1	17/17
PROM1	0/0	0/0	1/1	0/0	0/0	0/0	3/3	2/2	2/2	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	9/9
Subtotal	*0/0*	*3/3*	*1/1*	*0/0*	*0/0*	*0/0*	*3/3*	*4/4*	*8/8*	*	*1/1*	*1/1*	*0/0*	*2/2*	*	*0/0*	*2/2*	*1/1*	*26/26*
AT/LM																			
M19	0/1	1/1	0/0	0/0	0/0	2/2	0/0	1/1	0/0	*	0/0	1/1	0/0	0/0	*	0/0	0/0	0/0	5/6
TMA4	0/0	0/0	0/1	0/0	0/0	3/3	0/0	0/0	0/0	*	0/0	0/0	0/0	0/0	*	0/0	1/1	0/0	4/5
VS2.2	1/1	2/2	0/0	0/0	0/0	0/0	1/2	0/0	0/0	*	1/1	0/0	0/0	0/0	*	0/0	0/0	0/0	5/6
TM62P3	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	*	0/0	0/0	1/1	0/0	*	0/0	1/1	1/1	3/3
Subtotal	*1/2*	*3/3*	*0/1*	*0/0*	*0/0*	*5/5*	*1/2*	*1/1*	*0/0*	*	*1/1*	*1/1*	*1/1*	*0/0*	*	*0/0*	*2/2*	*1/1*	*17/20*
AP/LM																			
TS50	1/2	3/4	4/4	0/0	0/0	0/5	0/0	1/2	0/0	*	0/0	3/6	3/4	2/3	*	0/0	0/0	0/0	17/30
VS50	0/0	3/3	3/4	0/0	0/0	5/5	0/0	3/3	0/0	*	0/0	4/4	5/5	3/3	*	0/0	4/4	1/1	31/32
PMA3	0/0	3/4	0/0	0/0	0/0	2/4	1/2	0/0	0/0	*	0/0	0/0	0/0	0/0	*	0/0	0/0	0/0	6/10
Subtotal	*1/2*	*9/11*	*7/8*	*0/0*	*0/0*	*7/14*	*1/2*	*4/5*	*0/0*	*	*0/0*	*7/10*	*8/9*	*5/6*	*	*0/0*	*4/4*	*1/1*	*54/72*
AT/NM																			
EM12	0/0	0/0	0/0	2/2	0/0	0/0	1/2	0/0	0/0	*	0/0	2/2	3/4	1/2	*	4/9	0/0	0/0	13/21
EM6	0/0	0/0	0/0	0/0	0/0	0/0	0/1	0/2	0/0	*	0/1	0/0	0/0	2/2	*	2/7	1/3	0/0	5/16
Subtotal	*0/0*	*0/0*	*0/0*	*2/2*	*0/0*	*0/0*	*1/3*	*0/2*	*0/0*	*	*0/1*	*2/2*	*3/4*	*3/4*	*	*6/16*	*1/3*	*0/0*	*18/37*
AP/NM																			
EM3	0/0	0/2	0/3	1/2	0/0	0/0	0/0	0/2	0/0	*	0/0	0/0	1/5	0/2	*	3/5	1/1	1/2	7/24
Subtotal	*0/0*	*0/2*	*0/3*	*1/2*	*0/0*	*0/0*	*0/0*	*0/2*	*0/0*	*	*0/0*	*0/0*	*1/5*	*0/2*	*	*3/5*	*1/1*	*1/2*	*7/24*
Total	**2/4**	**17/21**	**8/13**	**3/4**	**0/0**	**12/19**	**6/10**	**9/14**	**11/11**	*	**3/4**	**12/15**	**14/20**	**11/15**	*	**9/21**	**12/14**	**4/5**	**133/190**

Legend:

AP/M = Antipersonnel
AP/LM = Antipersonnel/low metal
AP/NM = Antipersonnel/no metal
AT/M = Antitank/metal
AT/LM = Antitank/low metal
AP/NM = Antitank/no metal
* = Not searched.

APPENDIX B

MINE DETECTOR TEST TARGETS

APPENDIX B
MINE DETECTOR TEST TARGETS

Selecting and employing appropriate targets for mine detection tests is difficult. One must balance realism against safety and environmental conditions. This was a blind test with soldiers operating the detectors. The goal was to use actual mines to the fullest extent possible. For safety reasons, the firing chain was interrupted by removing the booster or detonator. When this was done, care was exercised to put back the actual demilled booster or detonator or a nearly identical part. Replacing these parts is particularly important when testing metal detectors, since these small parts often are the only metal in the mine. Since ground-penetrating radar sensors were also used, booster surrogates filled with material of the same dielectric constant as the explosive were employed. For metallic cored mines, the empty cases were again filled with an appropriate dielectric material. For high metallic antitank and antipersonnel mines (M12A1, M21, PROM1, VAL-69, the fuzes were left out entirely. The antitank mines were buried at either 10 cm or 1 cm below the surface, while the antipersonnel mines were buried at a depth of 1 cm. The following paragraphs describe each mine target and the configuration used during the test.

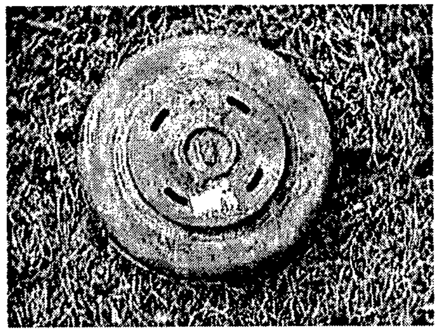
I. AT METAL

Type	Quantity	Source
M21	4	GOV'T

The steel case of the M21 is 8 in. high and 9 in. in diameter. This mine is primarily designed for use with a 24-in. tilt rod and contains a shape-charge plate. The mine can also be set up for pressure actuation as a blast mine.

The empty metal casings were filled with RTV 3110 rubber. Boosters/detonators, fuze, and tilt-rod were not installed due to the high metal content of mine.

I. AT METAL

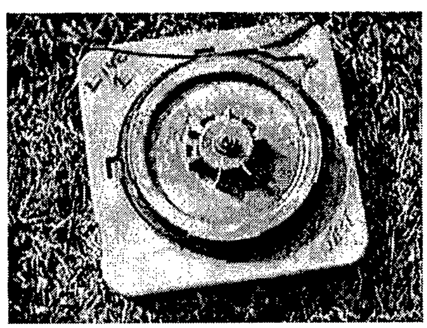


Type	Quantity	Source
M12A1	10	GOV'T

The steel case of the M12A1 is 5 in. high and 13 in. in diameter. The mine is a practice device which simulates the live M-15 mine.

The empty metal casings were filled with RTV 3110 rubber. No practice fuzes were installed due to the high metal content of mine.

II. AT LOW METAL



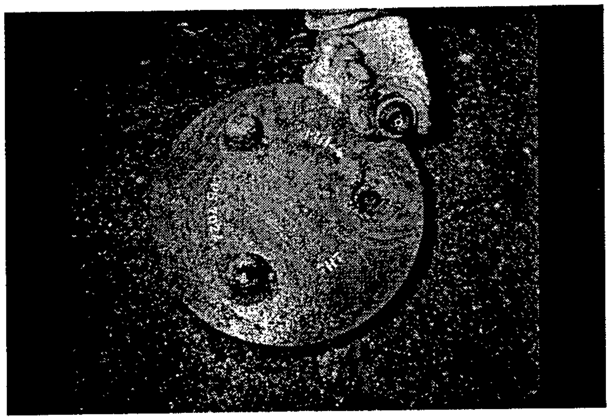
Type	Quantity	Source
M19	8	A.P. Hill

The M19 plastic antitank mine is approximately 4 in. thick and 13 in. square and weighs 28 lb. The blast mine contains 21 lb of explosive.

The main explosive charges were left intact. Boosters were removed and replaced with RTV 3120. Fully demilled detonators were reinstalled. Metal content of the detonators is approximately 0.7 g of copper. Mine also contains a 0.2-g metal firing pin for a total metal mass of 0.97 g. This is the actual metal mass contained in the test mines.

(The metal content of the M-19 is closer to 1 gram, not 2.5 grams indicated in some databases.)

II. AT LOW METAL

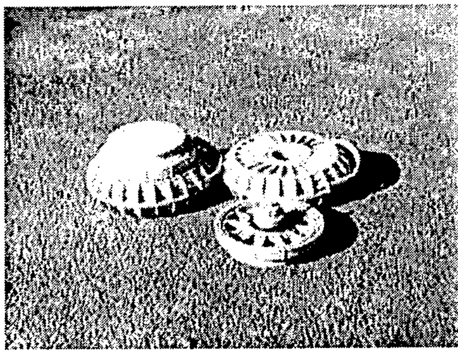
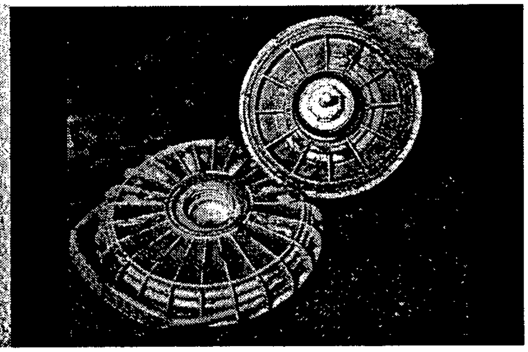


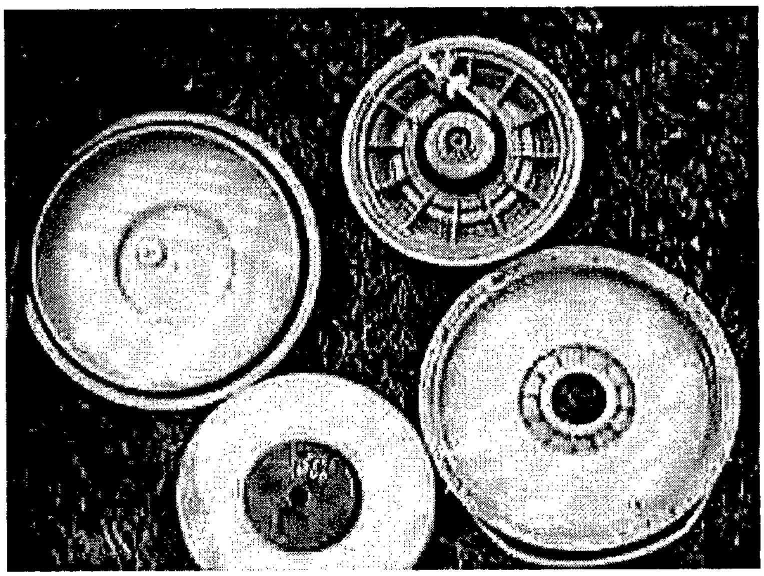
Type	Quantity	Source
TMA4	8	A.P. Hill

The TMA4 is a circular plastic pressure-activated antitank mine 11 in. in diameter and 4 in. high. It contains three top fuze wells.

Main explosive charges were left intact. Boosters were removed. Booster surrogates made of RTV 3120 rubber were installed below each detonator. Fully demilled detonators (three per mine) were reinstalled. Each detonator contained 0.3 g of aluminum alloy for a total of 0.9 g per mine.

II. AT LOW METAL

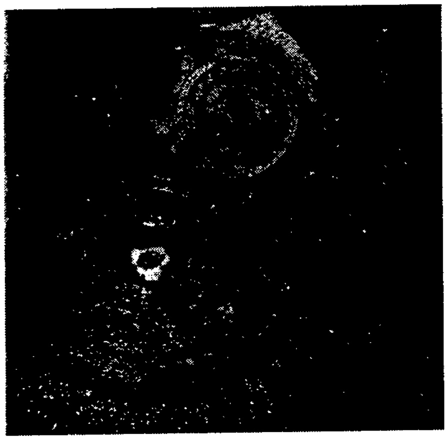


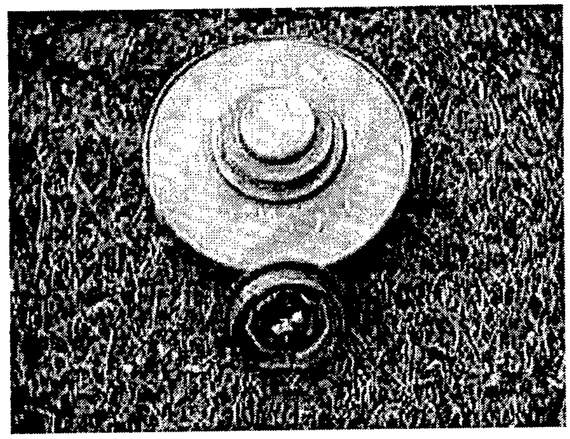
Type	Quantity	Source
VS2.2	8	A.P. Hill

The VS2.2 is a plastic antitank blast mine. It is 9 in. in diameter and 4-1/2 in. thick, with an explosive charge of 4.2 lb.

The main explosive charge was left intact. Booster surrogates made of RTV 3120 rubber were installed. Demilled detonators were reinstalled. Total metal content of the detonators was 0.9 grams of aluminum alloy. The mine also contains a 0.091-g metal firing pin, steel spring with a mass of 1.597 g, ball with a mass of 0.435 g, and a wire with 0.054 g mass, for a total metallic content of 3.077 g.

II. AT LOW METAL



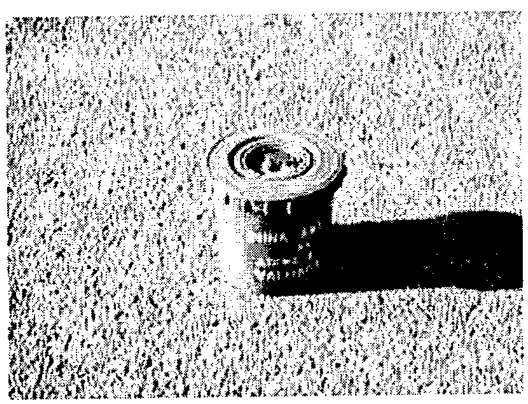


Type	Quantity	Source
TM62P3	6	VSE (Metal Parts)

The TM62P3 is a Soviet cylindrical plastic case mine, 4.5 in. high and 12.5 in. in diameter.

Demilled plastic casings were filled with RTV 3110 to simulate the main explosive charge. Fuze surrogates made of PVC were installed, with a total metal content of 3.8 g. This includes one vertical spring at 0.7 g, one horizontal spring at 0.9 g, and an aluminum block with 2.2 g mass. None of the metal parts were in contact with each other.

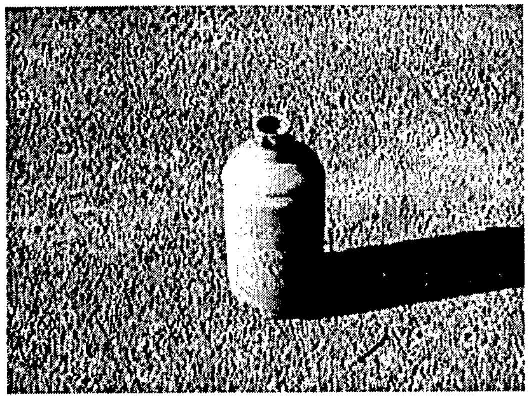
III. METAL AP



Type	Quantity	Source
VAL-69	20	A.P. Hill

The VAL-69 is another bounding fragmentation antipersonnel mine similar to the PROM1 except that the outer case is plastic. It is 8 in. high and approximately 4 in. in diameter.

The main explosive charge was left intact. Boosters and detonators were removed and not reinstalled due to the high metal content of mine.

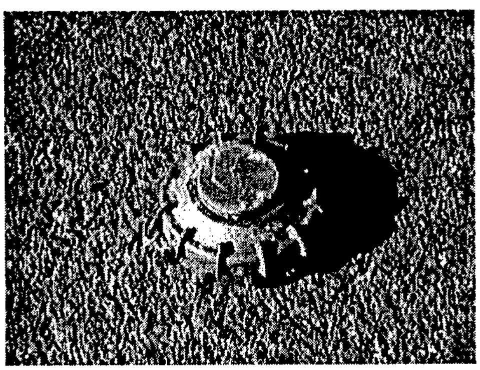


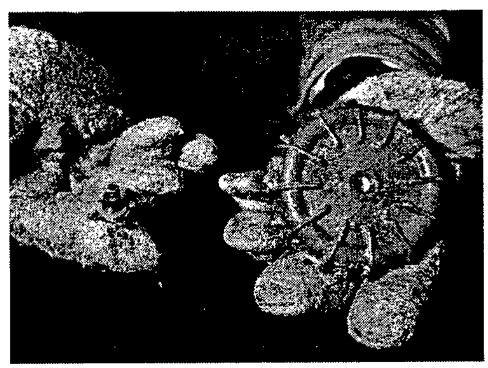
<u>Type</u>	<u>Quantity</u>	<u>Source</u>
PROM1	12	A.P. Hill

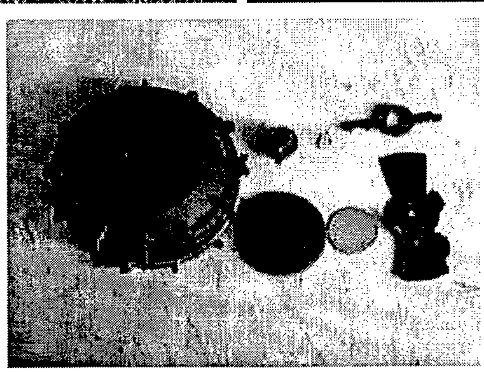
The PROM1 is a bounding antipersonnel mine made of steel. It is cylindrical in shape, 7 in. high (without the fuze) and 3 in. in diameter. It contains approximately 1/2 lb of explosive.

The main explosive charges were left intact. Boosters and detonators were removed and not reinstalled due to high metal content of mine.

IV. AP LOW METAL



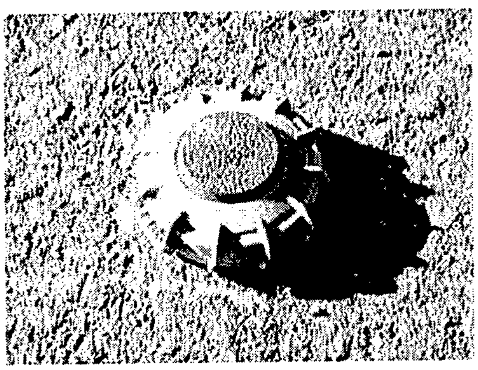


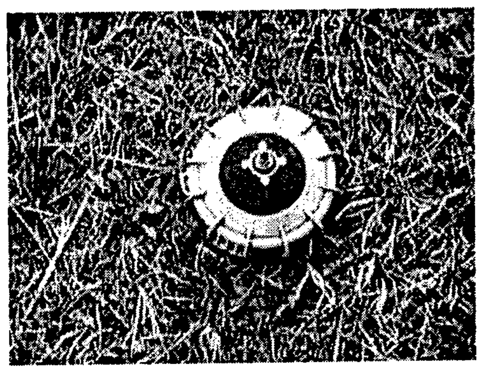


<u>Type</u>	<u>Quantity</u>	<u>Source</u>
TS50	46	A.P. Hill

The TS50 is a small plastic Italian antipersonnel mine similar to VS50. It is also 3-1/2 in. in diameter and 1.8 in. high.

The main explosive charge was left intact. Fully demilled detonators were reinstalled. Detonator contains 0.3 g of copper. The mine contains a nonmagnetic metal plate 14.3 mils thick, 240 mm in diameter, that has a mass of 3.49 g, and two springs, the first spring with mass 0.49 g and the second, 0.06 g. Both springs are made of magnetic steel. The firing pin, with a mass of 0.15 g, consists of two types of metal one magnetic, one not. The mine also contains two magnetic steel ball bearings that each have 0.05 g mass. Total metal content is 4.59 g.

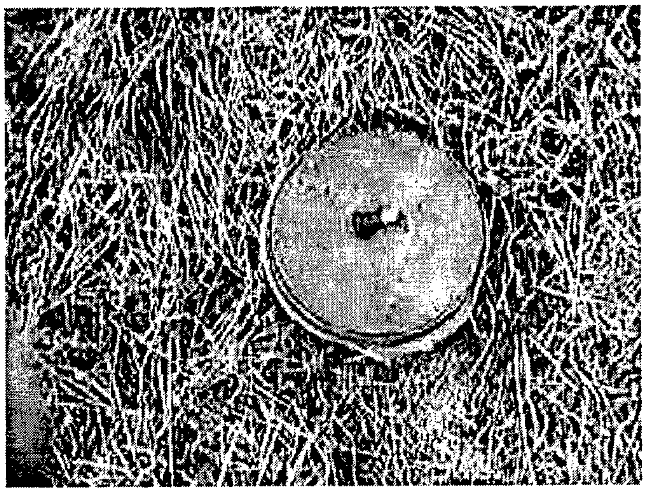




Type	Quantity	Source
VS50	46	A.P. Hill

The VS50 is a small, blast-resistant, Italian antipersonnel mine similar to the TS50. It is 1.8 in. high and 3-1/2 in. in diameter.

The main charges were left intact. Fully demilled detonators were reinstalled. Detonator contains 0.3 g of copper. The mine contains a magnetic steel plate 21 mils thick, 380 mm in diameter, with as mass of 17.49 g. The mine also contains a 0.49-g magnetic steel spring, and one 0.15-g metal firing pin. The firing pin consists of two types of metal, one magnetic, one not. Total metal content is 18.43 g.

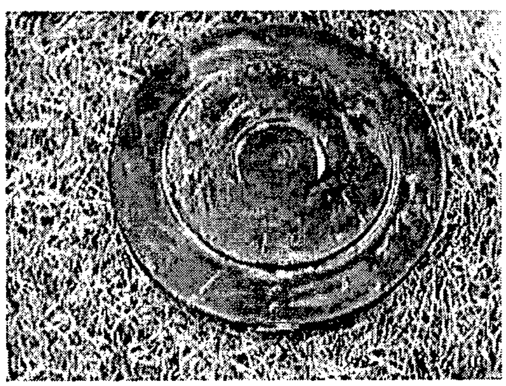


Type	Quantity	Source
PMA3	20	GOV'T

The PMA3 is a pressure-fuzed, blast-resistant AP mine. It is 4 in. in diameter and 1-1/2 in. thick.

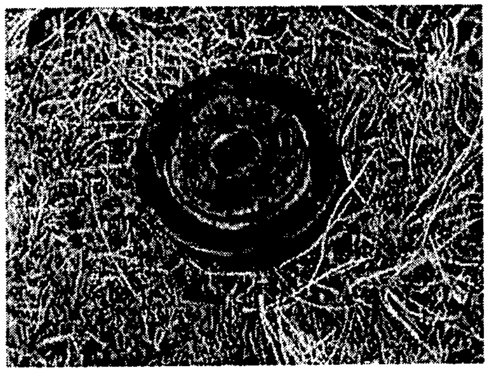
Demilled casings were filled with RTV 3110 to simulate the explosive charge. Fully demilled detonators were reinstalled. Metal content of the detonator is 0.3 g of aluminum alloy. The mine also contains a 1-3/8 in., 3/16-in. diameter spring (mild steel).

SURROGATES - FULLY NONMETALLIC



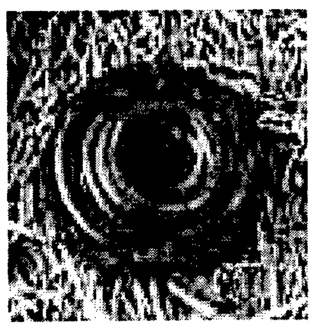
Type	Quantity	Source
12 in.	41	VSE

The surrogate is 3 in. thick and 12 in. in diameter. The case has a size and wall thickness similar to an actual landmine. The surrogate has a central fuze well in which small metallic pieces can be placed. No metal was used in these tests. The main feature of these surrogates is that they consistently match the electromagnetic properties of TNT over the frequencies of interest. Nonmetallic surrogates were filled with RTV 3110.



Type	Quantity	Source
6 in.	41	VSE

The surrogate is 2 in. thick and 6 in. in diameter. The case has a size and wall thickness similar to an actual landmine. The surrogate has a central fuze well in which small metallic pieces can be placed. No metal was used in these tests. The main feature of these surrogates is that they consistently match the electromagnetic properties of TNT over the frequencies of interest.



Type	Quantity	Source
3 in.	41	VSE

The surrogate is 1 in. thick and 3 in. in diameter. The case has a size and wall thickness similar to an actual landmine. The surrogate has a central fuze well in which small metallic pieces can be placed. No metal was used in these tests. The main feature of these surrogates is that they consistently match the electromagnetic properties of TNT over the frequencies of interest.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY ***(Leave blank)***

2. REPORT DATE
March 1998

3. REPORT TYPE AND DATES COVERED
Final January 1997–February 1998

4. TITLE AND SUBTITLE
Performance in December 1996 Hand-Held Landmine Detection Tests at APG: Coleman Research Corporation (CRC), GDE Systems, Inc. (GDE), and AN/PSS–12

5. FUNDING NUMBERS
DASW01 94 C 0054
T-AI2-1473

6. AUTHOR(S)
Anne M. Andrews, Thomas W. Altshuler, Erik M. Rosen, Lisa J. Porter

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Document D-2126

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Director of Defense Research and Engineering
OUSD(A&T)
Mine Detection Countermine Division
Ft. Belvoir, VA 22060

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 180 words)***

In December 1996, a test of three mine detection systems was held at Aberdeen Proving Ground, Maryland. This test compared prototype landmine detection systems manufactured by two contractors, Coleman Research Corporation (CRC) and GDE Systems, Inc. (GDE), with the Army's currently fielded electromagnetic induction mine detector, the AN/PSS–12. The two prototype systems under consideration integrate a ground-penetrating radar (GPR) with an electromagnetic induction metal detector. Both GDE the and CRC systems provide increased capability over the AN/PSS–12, but exhibited poor performance for detection of low-metallic and nonmetallic antipersonnel landmines.

14. SUBJECT TERMS
Mine Detection, Fort A.P. Hill, BOSHMIDS, Hand-Held Detectors, Metal Detector, Electromagnetic Induction, Ground-Penetrating Radar

15. NUMBER OF PAGES
86

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102